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#198 NOVEMBER 2021

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

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LUNAR RAYS

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THE REAL STARS OF BONFIRE NIGHT

Take an easy tour of the night sky in between the fireworks

RETURN OF THE COMET

Seek out the Rosetta mission's target, Comet 67P, in Gemini this month

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Welcome

Take in our nearest celestial neighbour this November

A favoured observing target of the late Patrick Moore, the Moon is putting on a show for us this month. However, as it's just past new, our natural satellite will be absent from proceedings on the night when seemingly everyone will be venturing out under the night sky – the 5 November, Bonfire Night. But don't miss the opportunity for an extra starry show in between the fireworks – turn to **page 28** for Stuart Atkinson's easy-to-take tour of the brighter stars and planets on the 5th.

A few days either side of the fireworks, keep an keen eye on the Moon's thin crescent phases for some beautiful close approaches with bright Mercury and Venus – their brightness pointing the way to the slender lunar crescents. There are also rare opportunities, thanks to libration, to take in features normally hidden just off the Moon's visible face, and a partial lunar eclipse visible on the 19th. Pete Lawrence has full observing details in the 'Sky Guide' on **page 43**.

The lunar phases around full Moon can be seen as a bit of a bugbear for astronomers, their brightness making fainter night-sky targets harder to observe and image. But in our feature on **page 60**, Will Gater will persuade you otherwise. For it's then that one of the most dramatic features of the lunar surface is best seen – the spectacular ray systems around the Moon's deepest craters. Picked out in dazzling brightness against the darker surroundings, their illumination gives a sense of the immense collisions that threw so much material so far across the lunar basalt. So have your telescope at the ready, perhaps with a neutral density filter on standby.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 18 November.

HOW TO CONTACT US

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Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

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Visit our website for competitions, astrophoto galleries, observing guides and more

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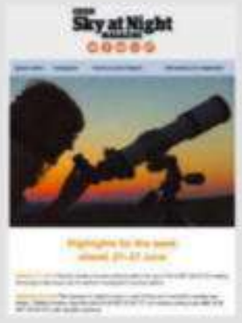

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The Sky Guide

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COVER IMAGE: MICHAEL KARRER/CCDGUIDE.COM. THIS PAGE: WILL GATER, BRIGHTSTARS/ISTOCK/GETTY IMAGES, MJ_PROTOTYPE/ISTOCK/GETTY IMAGES, JAXA, ESA/ROSETTA/NAVCAM, NASA GSFC/CIL/ADRIANA MANRIQUE GUTIERREZ, @THESHED_PHOTOSTUDIO, MOHAMMED BIN RASHID SPACE CENTRE, BBC

New to astronomy?

To get started, check out our guides and glossary at
www.skyatnightmagazine.com/astronomy-for-beginners

This month's contributors

Jane Green

Astronomy writer

"It was great to share that icy Ceres, no matter how it's been categorised in the past, has a thrilling history and is no underdog dwarf planet! **Jane enjoys unravelling the story of the planet that never was,** **page 72**

Emily Lakdawalla

Planetary scientist

"Recent missions have helped us understand Venus's sky and thick clouds. I can't wait for the next ones that'll see the ground underneath." **Emily updates us on the latest from missions at Venus,** **page 34**

Ezzy Pearson

News editor

"I reported on Rosetta throughout its original mission, when it visited Comet 67P, so it was a joy to see what's been happening in the years since" **Ezzy finds out how Rosetta is still informing our view of comets,** **page 67**

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/85UKFCX/** to access this month's selection of exclusive Bonus Content

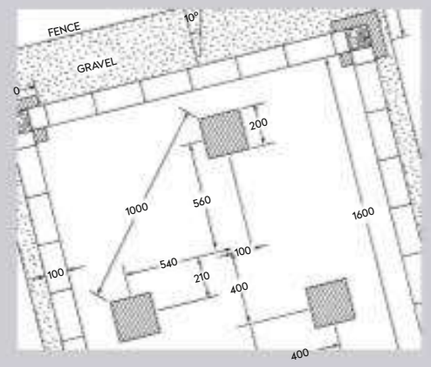
NOVEMBER HIGHLIGHTS

Interview: astronaut Nora Al Matrooshi

The UAE's first female astronaut discusses her ambitions and hopes for the future of spaceflight

Watch *The Sky at Night: Question Time Live*

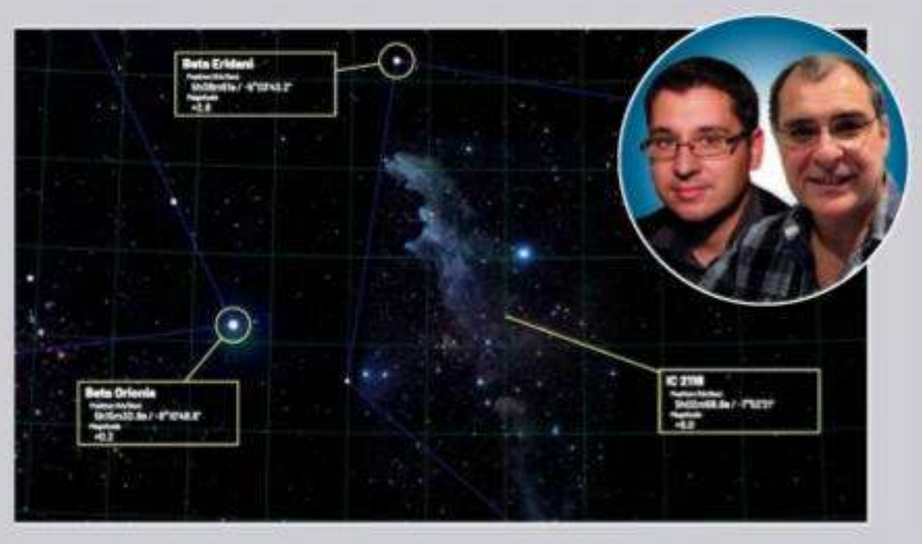
Maggie, Chris and Pete join a panel of experts to field questions on space and astronomy in front of a live studio audience



Build a roll-off roof garden observatory

Access plans and images to help with this month's project to build your own observing station. See page 76 for full details

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month

PRETTY PECULIAR

The odd-looking Centaurus A galaxy is revealed in incredible detail in this new image

VÍCTOR M BLANCO 4-METRE TELESCOPE, 31 AUGUST 2021

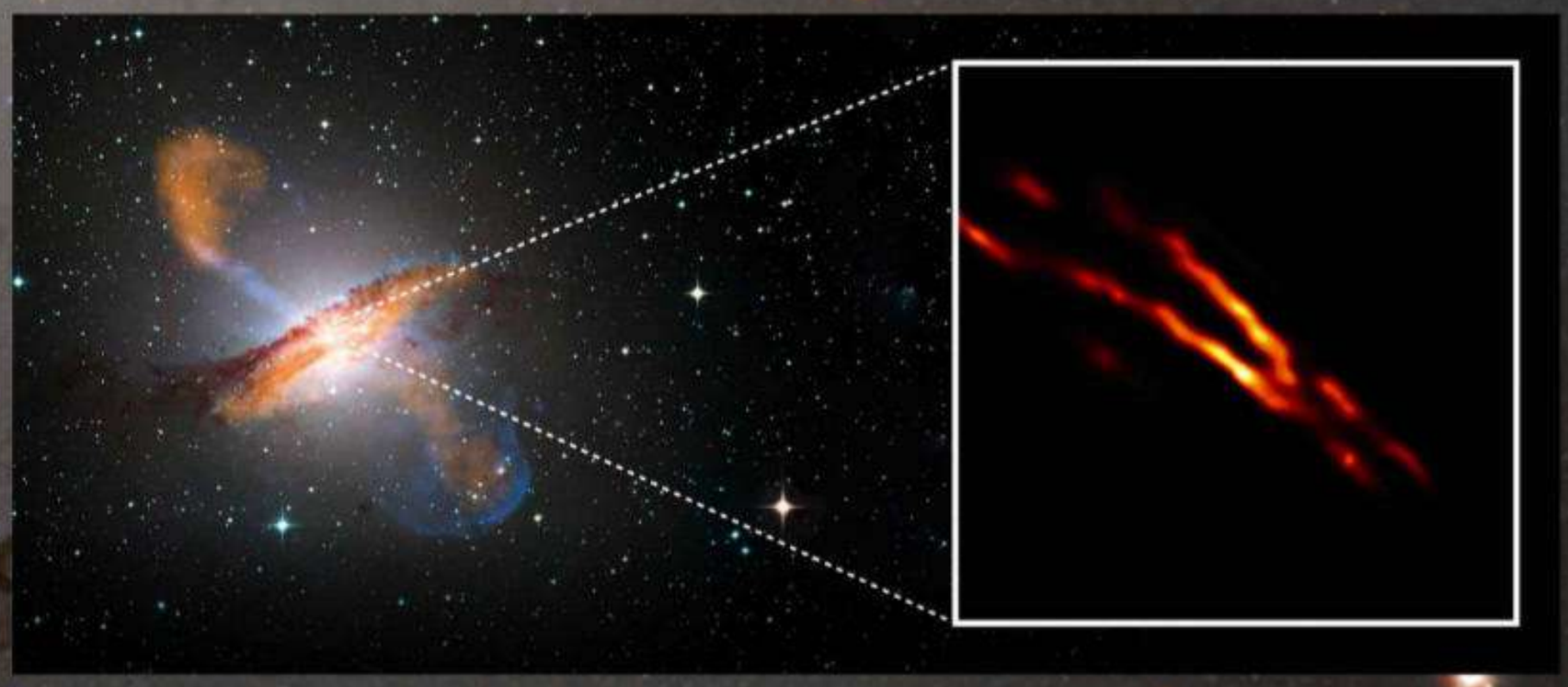
It may not have the conventional looks of a galaxy, but Centaurus A (also known as NGC 5128) is no less spectacular. It's one of the brightest objects in the night sky and, at just 12 million lightyears away, is a popular target for Southern Hemisphere observers. This new image from the Dark Energy Camera on the Victor M Blanco Telescope at the Cerro Tololo Inter-American Observatory (CITO) in the Chilean Andes, captures Centaurus A in extraordinary detail.

Its unorthodox appearance is the result of a shroud of dust and gas that blots out the elliptical galaxy's bright nucleus. These intricate, dark wisps are sprinkled with faint blue stars born from red clouds of hydrogen. They are the remnants of Centaurus A's last big meal: a spiral galaxy.

What this image doesn't show, are the gigantic jets of matter shooting from the supermassive black hole at its centre, recently captured by the Event Horizon Telescope (see inset).

MORE ONLINE

A gallery of these and more stunning space images



CTIO/NOIRLAB/DOE/NSF/AURA, RADBOUD UNIV. NIJMEGEN; CSIRO/ATNF/I. FEAIN ET AL., R. MORGANTI ET AL., N. JUNKES ET AL.; ESO/WFI; MPIFR/ESO/APEX/A. WEISS ET AL.; NASA/CXC/CFA/R. KRAFT ET AL.; TANAMI/C. MÜLLER ET AL.; EHT/M. JANSSEN ET AL

△ Twinkle, twinkle

TIANGONG SPACE STATION, 30 JULY 2021

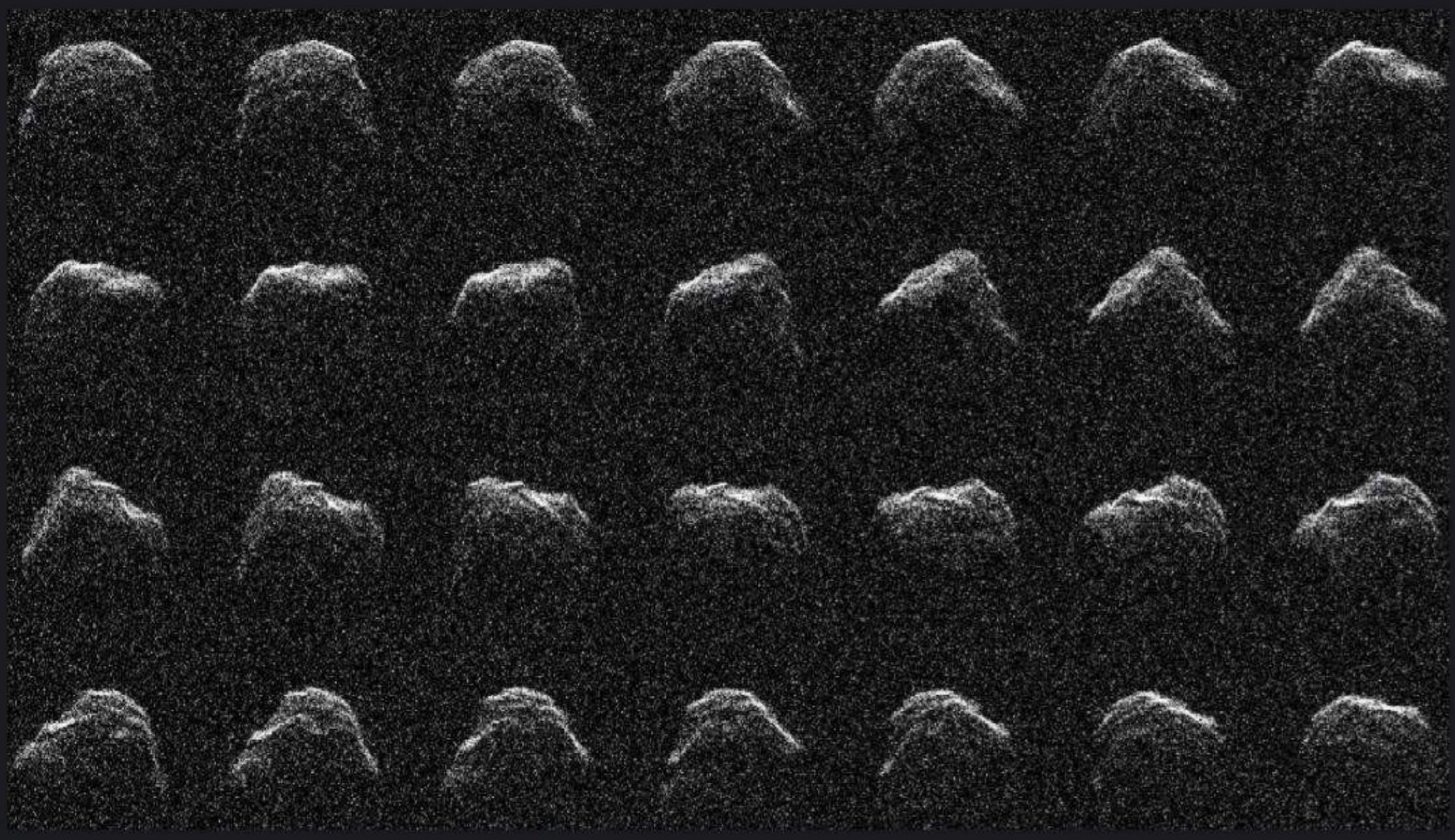
Thousands of lights across north Africa gleam as the Tiangong Space Station glides overhead. Chinese astronauts Tang Hongbo, Nie Haisheng and Liu Boming spent three months living in the station's brand-new Tianhe core module – China's longest crewed space mission to date – before landing safely back on Earth on 17 September. Two more modules will be fitted to the station in 2022, which will eventually include science labs, a gym and the Hubble-class Xuntian telescope.

TANG HONGBO/CHINA MANNED SPACE ENGINEERING OFFICE, JOSÉ LUIS PEREIRA, NASA/JPL-CALTECH, ESA/HUBBLE AND NASA, WILL GATER

◁ Jupiter takes a hit

JOSÉ LUIS PEREIRA, 13 SEPTEMBER 2021

A Brazilian amateur astrophotographer captured this bright flash on Jupiter's surface while filming the transit of Io's shadow. Other observers have confirmed the sighting of what's thought to be a large object, possibly a fragment of a passing comet or asteroid, hitting the planet. Jupiter has long been considered a 'buffer' in our Solar System, its massive gravity pulling in space debris that might otherwise head towards Earth.



△ Like a rolling stone

GOLDSTONE DEEP SPACE COMMUNICATIONS COMPLEX, 3 SEPTEMBER 2021

This series of pictures shows the 1.3km-wide Asteroid 2016 AJ193 as it tumbled past Earth in August. Detected by the 70m-diameter Deep Space Station 14 antenna in NASA's Goldstone Deep Space Communications Complex, the radar images reveal the asteroid's ridges, small hills and flat areas, as well as what might be boulders on its surface. Although classed as a Potentially Hazardous Asteroid, 2016 AJ193's stable, 5.9-year orbital path around the Sun has kept it at least 3.4 million kilometres away from Earth.

Burning bright ▷

WILL GATER, SOMERSET, UK, 27 SEPTEMBER 2021

The Centaur upper stage of an Atlas V rocket – which had just delivered the Landsat 9 satellite mission into orbit – passes over the UK, venting fuel into space, after carrying out a deorbit burn. The clouds produced by the venting and burn are scattering sunlight and so appear bright against the starry sky.

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The latest astronomy and space news, written by Ezzy Pearson

BULLETIN

Perseverance pays off

The Martian rover collected a rock sample on its second try

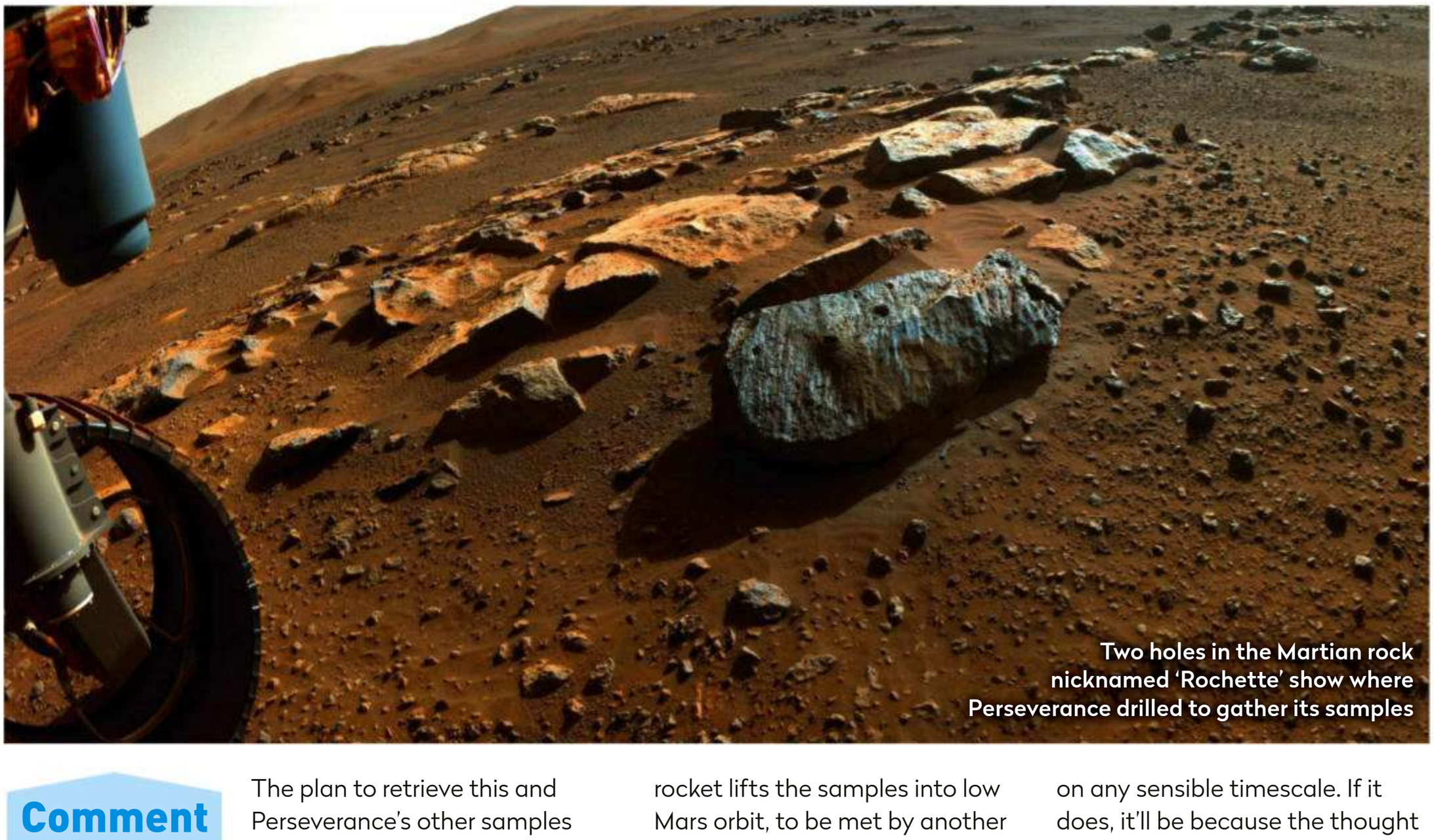
NASA's Perseverance rover has lived up to its name by successfully cacheing its first sample of Martian rock on Monday 6 September, after a failed attempt back in August. To prevent a second disappointment, the rover used its CacheCam to visually confirm there was Martian material in the sample tube after drilling. Another sample was acquired from the same rock on 8 September.

The ultimate goal of the mission is to learn how Mars's climate changed over time, as well as looking for signs of past life by cacheing samples of rock that will be returned to Earth by a future mission. Perseverance is currently exploring Jezero Crater, which was once home to an ancient lake. It's uncertain how long the lake persisted or when it disappeared, but once the samples have been returned to Earth, geologists will be able to accurately date when they were created.

"These samples have high value for future laboratory analysis back on Earth," says Dr Mitch Schulte, NASA's mission programme scientist. "One day, we may be able to work out the sequence and timing of the environmental conditions that this rock's minerals represent. This will help answer the question of the history and stability of liquid water on Mars."

The rover's next sample site will be from South Séítah, a series of ridges and sand dunes 200m away. This region is expected to be much older, giving a window onto a different era of Mars's history.

mars.nasa.gov/mars2020



Two holes in the Martian rock nicknamed 'Rochette' show where Perseverance drilled to gather its samples

NASA/JPL-CALTECH

Comment

by Chris Lintott

The plan to retrieve this and Perseverance's other samples starts with a joint NASA and ESA mission to touch down near to Perseverance in 2026.

An as-yet-undesigned rover will bustle about collecting samples left by Perseverance, and return them to a rocket that's also still on the drawing board. That rocket lifts the samples into low Mars orbit, to be met by another new spacecraft, which returns the samples to Earth by 2031.

That's three new spacecraft attempting a feat unmatched by anything since Apollo, at a time when NASA and ESA are both stretched in different directions. I struggle to believe it will happen on any sensible timescale. If it does, it'll be because the thought of the samples Perseverance is collecting – sitting there, ready but out of reach – is too tempting to resist. Mars's answers are waiting for us now if we can afford to go and get them.

Chris Lintott co-presents *The Sky at Night*

ESA/HUBBLE/NASA AND G. PIOTTO ET AL., NASA/JPL-CALTECH X 2, SPACEX, ORBEX

▲ **White dwarf stars in two globular clusters were still undergoing thermonuclear activity, casting doubt on the way stars are dated**

White dwarfs slow down their ageing

The stars could still be burning hydrogen in their outer layers

White dwarfs could be lying about their age by hiding behind a youthful veil of hydrogen, a new study has found.

These small, dense stars represent the final stage in the life cycle of most stars, when they have thrown off their outer layers of hydrogen, leaving only the core behind. The current understanding of white dwarfs is that all fusion within them has stopped and that they are cooling down over time. This creates a strong link between a star's temperature and its age, which astronomers make use of to date how old stars are. However, a new set of observations made with the Hubble Space Telescope has thrown this relationship into doubt.

"We have found the first observational evidence that white dwarfs can still undergo stable thermonuclear activity," says Jianxing Chen from Alma Mater Studiorum Università (AMSU), who led the study. "This was quite a surprise as it's at odds with what is commonly believed."

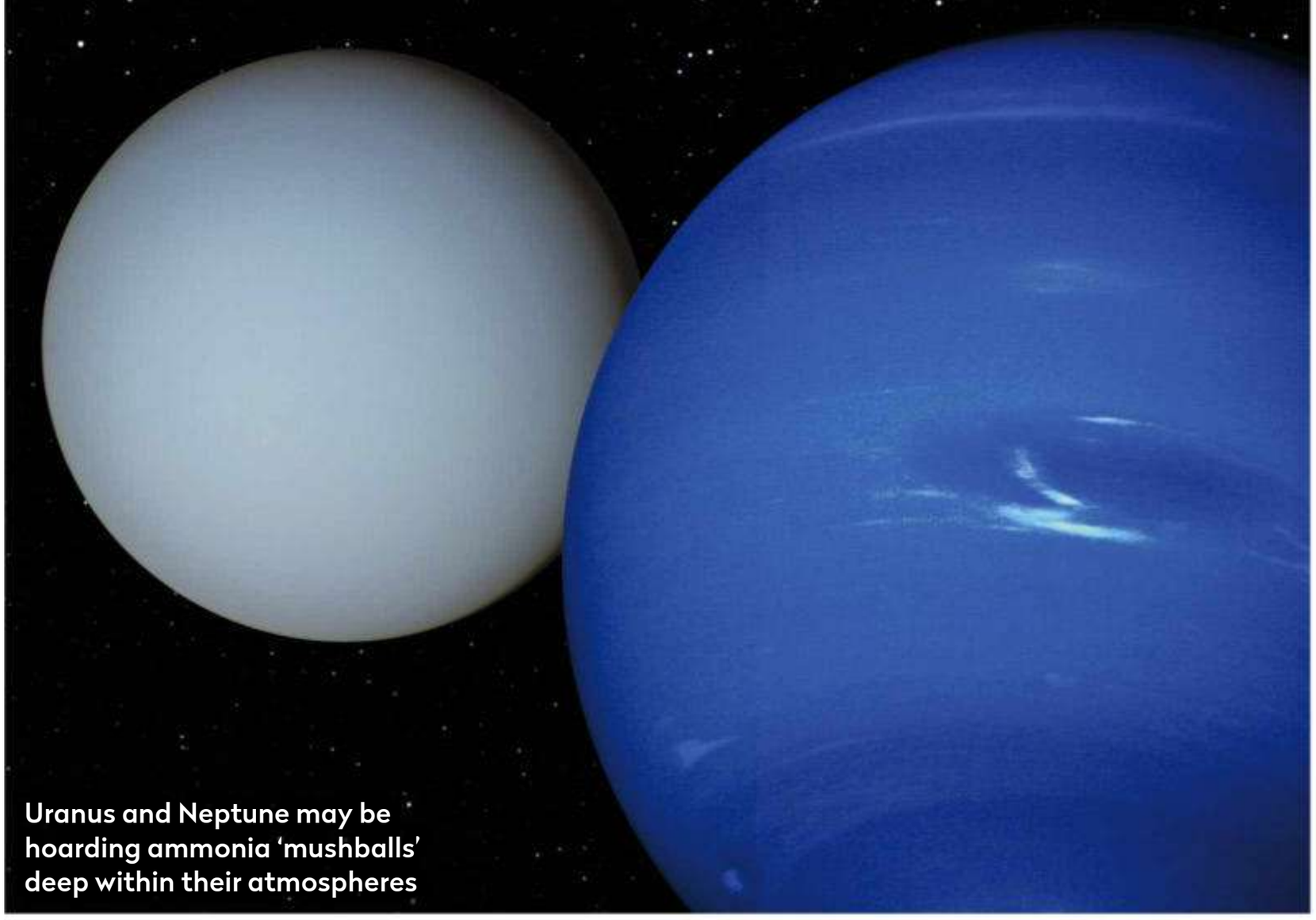
The study compared the white dwarfs in two globular clusters, M13 and M3. The clusters are similar in age and metallicity (how many elements they have other than hydrogen and helium), but have differences in the stellar populations that are expected to go on to become white dwarfs. That makes them the perfect testing grounds to see how these stars cool over time.

"The superb quality of our Hubble observations provided us with a full view of stellar populations in the two globular clusters," says Chen. "This allowed us to really contrast how stars evolve in M3 and M13."

Chen and his team were able to see that M13 contained a population of stars that were still burning hydrogen in their outer layers, which slowed their cooling, making them appear more youthful than they actually are.

"Our discovery challenges the definition of white dwarfs as we consider a new perspective on the way in which stars get old," added Francesco Ferraro, also from AMSU, who coordinated the study. "We're now investigating other clusters that are similar to M13 to further constrain the conditions that drive stars to maintain the thin hydrogen envelope which allows them to age slowly."

www.hubblesite.org



ILLUSTRATION

Uranus and Neptune may be hoarding ammonia 'mushballs' deep within their atmospheres

Ice giants' secret ammonia stash

The outermost planets could be burying the gas in hailstones

Neptune and Uranus could be storing ammonia deep in their atmospheres as 'mushballs' – hailstones made of ammonia and water. The planets appear to lack ammonia compared to other planets, and Tristan Guillot from the Laboratoire Lagrange in Nice might have found out why in his latest study, which searched for the answer on Jupiter.

"The Juno spacecraft has shown that on Jupiter ammonia is present in abundance, but generally much deeper than expected – thanks to the formation of mushballs," says Guillot.

These mushballs form in storms at high altitude, trapping ammonia inside. Weighing up to a kilo, they fall through the atmosphere carrying the ammonia with them. On Uranus and Neptune, the portion of the atmosphere that forms mushballs is much higher.

"Thus, ammonia is probably simply hidden in the deep atmospheres of these planets, beyond the reach of present-day instruments," says Guillot.
lagrange.oca.eu/en/welcome-lagrange

Amateur astronauts orbit the Earth

The world's first ever spaceflight crewed entirely by 'amateur astronauts' launched from the Kennedy Space Center on 15 September. The crew of the Inspiration4 mission spent three days in orbit on board one of SpaceX's Crew Dragon modules, returning to Earth on 18 September by splashing down into the Atlantic Ocean.

Jared Isaacman (far left) and the Inspiration4 crew experience weightlessness

The flight was commanded and paid for by billionaire Jared Isaacman. He was accompanied by Helen Arceneaux, a paediatric cancer survivor and the first person in space with a prosthetic limb; Dr Sian Procter, the first black woman to pilot a spacecraft; and Chris Sembroski, who won his seat in a contest to raise money for St Jude Children's Research Hospital.

The mission orbited at 575km, over 150km above the International Space Station (ISS). As the radiation at this altitude is more intense, the crew participated in a number of medical studies to see how each of their bodies coped with the flight.

Then, on 5 October, a Russian actress and director spent 12 days on the ISS filming the first movie shot in space, beating Tom Cruise who announced his plans to film on the ISS last year.
inspiration4.com

NEWS IN BRIEF

UK aims to become space leader

The UK government released a new space strategy on 27 September, outlining its plans to make the nation into a space powerhouse. The strategy aims to ensure the UK is a strong pillar in a global space economy by growing home talent and strengthening international partnerships.

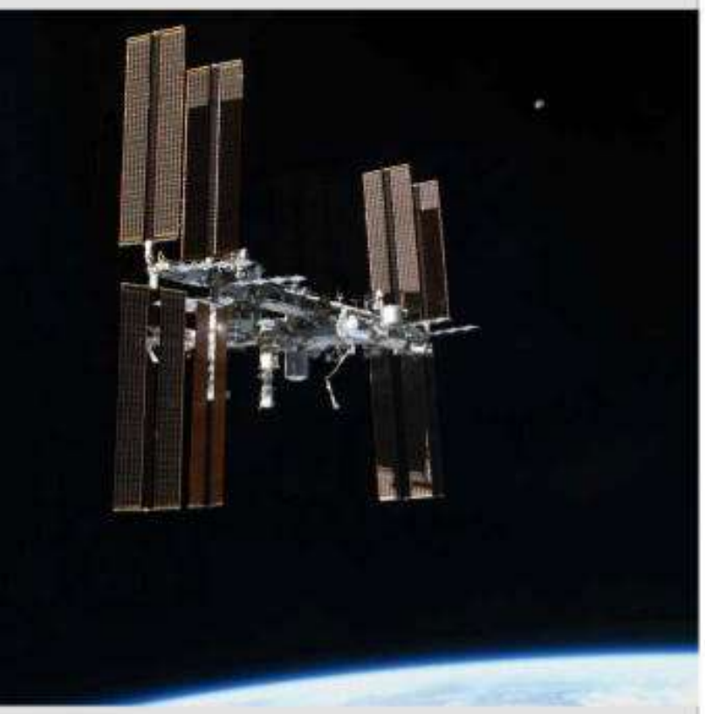
SLS launch slips

Hopes that NASA might launch its new Space Launch System in 2021 are waning. Though there have been no major delays, several key milestones have missed their deadlines. The rocket now won't leave the Vehicle Assembly Building until late November, leaving little time for tests if NASA hopes to launch this year.

Supernovae due in 2037

The last light from the Requiem supernova, first spotted in 2016, will arrive at Earth around 2037, it has been predicted. Gravitational lensing has split Requiem's light into several images. Three have already been observed but the last has a longer path to reach Earth.

NEWS IN BRIEF



Fire alarm on ISS

A smoke alarm went off on the ISS on 9 September, after astronauts reported the smell of burning coming from the Russian segment. Much of the Russian systems are past their warranty date and are in need of replacing. This casts doubt over how long the ISS can continue to operate.

Planetary hot-spots

Astronomers have mapped the temperature profile of a protoplanetary disc, confirming that planets are forming within the disc for the first time. The team used the radiation given off from carbon monoxide molecules, which decreases with temperature, as a natural thermometer.

New stargazing centre for Yorkshire

A new Star and Nature Hub has opened at the Sutton Bank National Park Centre in North Yorkshire. The hub will host regular stargazing events and is equipped with red lighting and outdoor seating, offering a relaxing place to absorb the surroundings.

NASA, ESA/BEPICOLOMBO/MTM, NASA/JPL-CALTECH

BULLETIN

BepiColombo's first images of Mercury

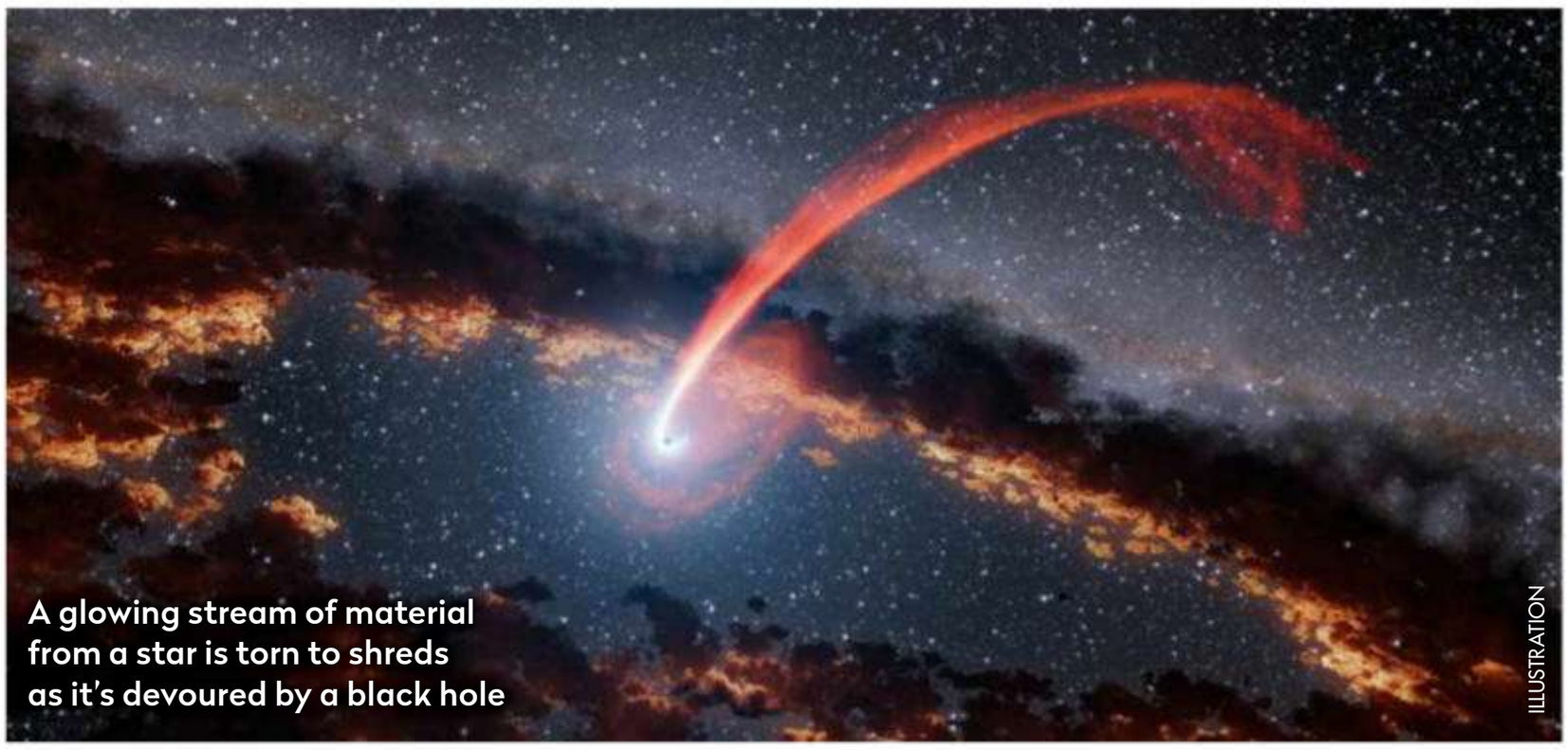
The mission will have five more flybys before entering orbit

The BepiColombo spacecraft made its first flyby of Mercury on 1 October, passing just 200km from the planet's surface and capturing its first up-close image. The pass was one of nine gravity assist manoeuvres – one at Earth, two at Venus, six at Mercury – where the spacecraft gets a free speed adjustment by swinging past a planet. This should allow BepiColombo to match speeds with Mercury and enter orbit in 2025.

These initial images were snapped from a distance of 2,418km from the planet's Northern Hemisphere, showing the Sihtu Planitia area, which was once smoothed over by a flood of lava that has now become pockmarked by meteor strikes. It also shows the 166km-wide Lermontov crater, containing a feature unique to Mercury – hollows, where volatile elements have explosively escaped. **www.esa.int**

BepiColombo images reveal a landscape ravaged by meteor strikes

Black hole gives clue on dark matter



A glowing stream of material from a star is torn to shreds as it's devoured by a black hole

ILLUSTRATION

Astronomers have taken advantage of a black hole's messy eating habits to make measurements of the mass and spin of one of these objects for the first time, giving a potential clue about the nature of dark matter.

When black holes gobble up stars, they create a huge outburst of radiation, known as a tidal disruption event, that can outshine the black hole's host galaxy. Astronomers observed one of these events, J2150, from an intermediate mass black hole, then compared observations to computer models showing that the black hole is 10,000 solar masses in size.

They were also able to determine the spin of the black hole – a key measurement to astrophysicsts investigating whether dark matter is made of hypothetical particles known as ultralight bosons.

"If those particles exist and have masses in a certain range, they will prevent an intermediate-mass black hole from having a fast spin," says Nicholas Stone from the Hebrew University in Jerusalem, who took part in the investigation. "Yet J2150's black hole is spinning fast. So, our spin measurement rules out a broad class of ultralight boson theories, showcasing the value of black holes as extraterrestrial laboratories for particle physics." **https://en.huji.ac.il/en**

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

Big or small, every legacy gift left to the Stroke Association will make a difference to stroke survivors and their families.

Find out how by calling 020 7566 1505

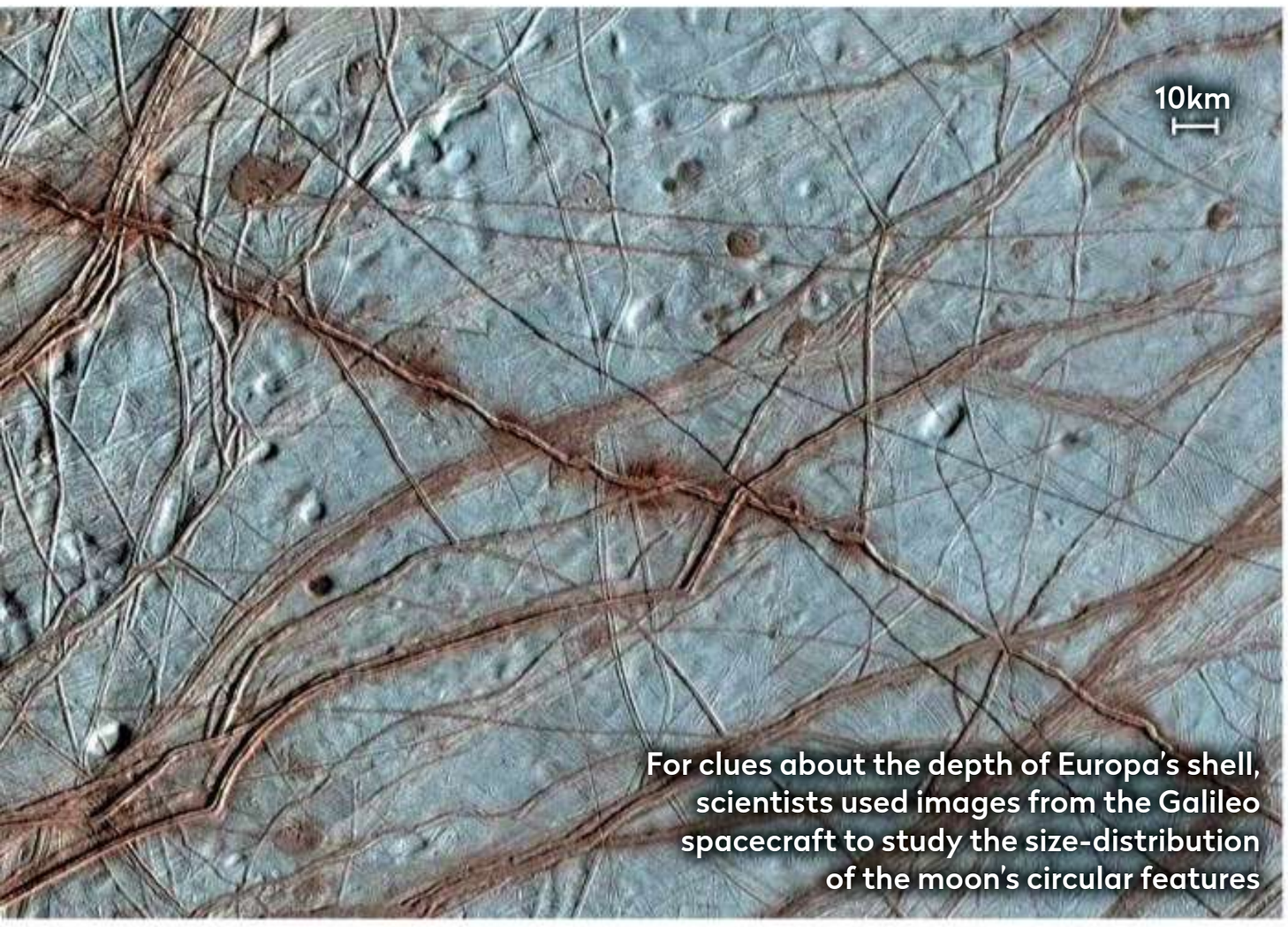
or email legacy@stroke.org.uk

or visit stroke.org.uk/legacy

Rebuilding lives after stroke

The Stroke Association is registered as a charity in England and Wales (No 211015) and in Scotland (SC037789).
Also registered in the Isle of Man (No. 945) and Jersey (NPO 369), and operating as a charity in Northern Ireland.

Stroke Association



For clues about the depth of Europa's shell, scientists used images from the Galileo spacecraft to study the size-distribution of the moon's circular features

Getting under Europa's skin

Surface features could reveal the thickness of the icy shell around Jupiter's moon

Europa is a very dynamic and fascinating moon. Its surface is only between 40 to 90 million years old (as determined by crater counts), which indicates that it is constantly renewing its face. The Europan surface is absolutely smothered with landforms that suggest ongoing geological processes: long ridges, large regions of broken-up 'chaotic' terrain, and smaller areas of uplift and circular pits. It's also clear that underneath its hard-frozen surface Europa harbours a deep ocean of liquid water.

But one of the biggest mysteries surrounding Europa is just how thick that shell of ice really is. And solving this is crucial to understanding the moon's internal structure, its geological history, and even the chances its hidden ocean offers a habitat for extraterrestrial marine life.

There's a huge ongoing debate within the planetary science community, split between the thin and thick icers. Is the icy shell thin enough that the ocean below can occasionally melt all the way through and break up the surface to create the observed chaotic regions? Or is the ice layer pretty thick, with the landforms instead being created by solid-state convection within the moon's shell? Thick icers say blobs of relatively warm ice rise buoyantly to deform the surface.

The problem is that different scientists can look at the same images of surface features on Europa – mostly taken by the Galileo probe in the late 1990s – and come to completely opposing conclusions. Now, Kelsi Singer at the Southwest Research Institute, Boulder, Colorado, and her colleagues have taken a fresh look at the conundrum. They've mapped all the roughly circular features, between 1km and 50km in size, visible in the available imagery of Europa that could plausibly have been created by internal geological processes. They were also able to make use of new topographic datasets on details of the landscape, such as the gradient and height or depth of features.

What lies beneath?

What they found when analysing their data on the size-distribution for all the identified pits, uplifts and small chaotic regions is that there is a peak at around 5km-6km in diameter. Features smaller or larger than this are found to be less and less common. In fact, Singer and her team weren't able to find any pits at all that were smaller than 3.3km in diameter, even in the highest-resolution images.

"Underneath its hard-frozen surface Europa harbours a deep ocean of liquid water. But one of the biggest mysteries is just how thick that shell of ice is"

This size-distribution, they say, goes against what you would expect to find if the Europan ice shell were thin enough for melt-through events to occur. So Singer concludes that their analysis supports the interpretation that the surface features are produced by rising warm ice, and therefore that the Europan ice shell is likely thick rather than thin. They calculate that the ice shell must have been at a minimum 3km to 8km thick when these surface features formed.

But all of this is still just best-guess inferences on the thickness of Europa's ice shell. The good news is that the high-resolution imaging and, in particular, ground-penetrating radar measurements promised by future missions such as ESA's JUICE (JUpiter and ICy moons Explorer) or NASA's Europa Clipper may soon be able to settle this debate once and for all.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Pits, Uplifts and Small Chaos Features on Europa: Morphologic and Morphometric Evidence for Intrusive Upwelling and Lower Limits to Ice Shell Thickness* by Kelsi N Singer et al.
Read it online at: https://arxiv.org/abs/2108.01795

NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA, MXW STOCK/ISTOCK/GETTY IMAGES

Measuring the mass of the Milky Way

Our Galaxy's smaller siblings could hold the secret to its size

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

At times our ignorance about the Universe around us is breathtaking. Often I realise that a fact that I'd taken for granted is being called into question – the identity of the closest star to the Sun, for example, and the length of the day on Saturn are both up for debate. On larger scales, we don't really have a satisfactory measure of our own Galaxy's mass.

Weighing the Milky Way is an exercise in more than just idle curiosity, too. Studying our Galaxy is one way that cosmologists test their ideas about how still-mysterious dark matter shapes the formation of galaxies. One particular problem is that our home system seems to have too few satellites in orbit around it, a problem which goes away if we have a Milky Way which is less massive than expected; lighter central galaxies have a less populated retinue.

Those dwarf galaxies we do have are a little unexpected in themselves. They turn up in odd places, preferring to sit above the Galaxy's poles than along its disc, and more of them seem to have ceased substantial star formation than in similar systems we see elsewhere.

Using satellite galaxy data

The opportunity to see whether these mysteries can be resolved by sorting out the Milky Way's mass comes from the latest data release from ESA's Gaia satellite, which is busy mapping and recording the movements of nearly two billion stars. Though the bulk of the data describes stars within our Galaxy's main disc, enough have been identified in satellite galaxies that the team behind this month's paper have been able to work out how these miniature systems are moving in relation to the Milky Way.

Because their motion is controlled by the pull of the Milky Way's gravity, watching the satellites move, and comparing those movements to the esoterically named Phat ELVIS suite of simulated galaxies, gives us a measure of mass. In contrast to methods which involve counting stars, because we're measuring the effect of gravity itself we get a value for the total mass, including both normal baryonic matter and that pesky dark matter.

In practice, the team are comparing properties of the galaxy population, such as the speed in which satellites are moving towards or away from the Milky Way. In an ideal world they'd be able to measure the time since each satellite first entered the Milky Way halo. Unfortunately, that's best determined by travelling back in time, and as the team note that they lack a *Back to the Future*-style DeLorean, they can't compare this value with simulations.

"The team are comparing properties of the galaxy population, such as the speed in which satellites are moving towards or away from the Milky Way"

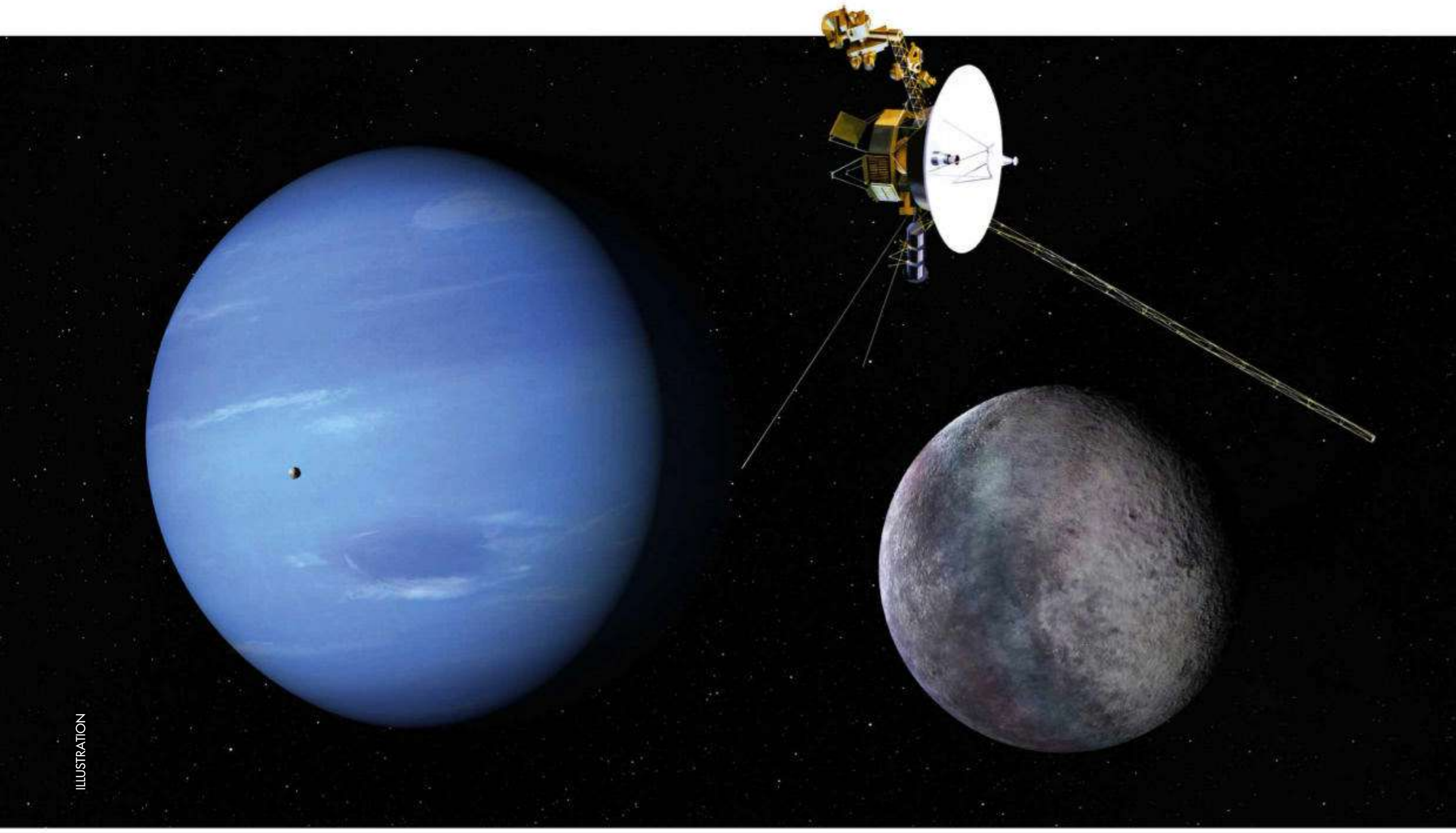
Nonetheless, the results look convincing, with the Milky Way weighing between 1 and 1.2 trillion solar masses. That's high enough that the missing satellite problem still exists; future surveys, including that carried out by the Vera Rubin Observatory (now under construction in the Atacama desert), should expect to detect more small companions of the Milky Way, each of which will ease the worries of cosmologists and, as a bonus, add to our ability to measure the mass of the Galaxy we call home.

Data from the Milky Way's satellite galaxies, such as the Large and Small Magellanic Clouds (left and right), is helping with research into our Galaxy's mass

Chris Lintott was reading... *Sizing from the Smallest Scales: The Mass of the Milky Way* by MK Rodriguez Wimberly et al. **Read it online at: https://arxiv.org/abs/2109.00633**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



ILLUSTRATION

IANM35/ISTOCK/GETTY IMAGES, BENJAMIN JOHN/ALAMY STOCK PHOTO, ADRIANA MANRIQUE GUTIERREZ, NASA ANIMATOR

As Neptune and Uranus could solve the mysteries of planet formation, we need to go back and study them in depth, says **Leigh Fletcher**

▲ Voyager 2 was the last spacecraft to encounter Neptune and its largest moon, Triton, back in 1989

During the 1980s, the Voyager 2 spacecraft transformed our view of the ice giants, Uranus and Neptune, from mere wandering points of light to complex and beautiful planetary systems. The Voyager data remains a treasure trove of information on the planets' interiors, atmospheres and diverse satellites. But with only a single encounter recorded for each planet, we haven't even scratched the surface of these worlds. Out there on the 'frozen frontier', discoveries await the next robotic explorers. Today, the international community is lobbying space agencies to mount a mission to these ice giants, the only major class of planet yet to have a dedicated orbital explorer.

The scale of the challenge is matched by the scientific importance of these two worlds. As we gaze out to extrasolar planets, we've realised that worlds of a similar size to our ice giants are commonplace. By contrast, the larger gas giants like Jupiter and Saturn seem rare. And yet we still struggle to understand how Uranus and Neptune formed. Giant planet formation is essentially a race between accretion of gas onto an embryonic rock-ice core, and the dissipation of that gas. To achieve worlds similar in size to Uranus and Neptune requires fine-tuning of this relationship and we need to know much more: How much ice and rock is present in these ice giants? How is material distributed? How have these worlds been cooling since their formation? To understand their evolution, we need a mission capable of measuring gravitational and magnetic fields, directly sampling the planetary composition, and studying the atmospheres and magnetospheres.

The ice giants are the missing link, the piece of the puzzle to help us unlock the mysteries of planet formation. Uranus presents extreme seasons and magnetic fields, a consequence of the cataclysmic

Leigh N Fletcher is an Associate Professor in Planetary Science at the University of Leicester

impact that tilted it onto its side; whereas Neptune's powerful meteorology is driven by heat from within that's absent (or locked away) on Uranus. Uranus has a classical system of satellites and delicate rings. Neptune, conversely, possesses an interloper from the Kuiper Belt: the massive moon Triton. These worlds can't be effectively studied remotely, we have to visit them with sophisticated new spacecraft in order to reveal terrains that were in total darkness for Voyager 2, 30 years ago.

With such tantalising potential for discoveries, why haven't we returned to the ice giants since the 1980s? Reaching 20 or 30 AU requires an international effort and some good timing. With today's rockets and chemical propulsion, we need to slingshot around Jupiter, to get as much mass as possible into orbit around Uranus or Neptune. That means Jupiter must be in just the right place, which happens once every 12–13 years. The next window is in the early 2030s, so we have no time to lose. ESA and NASA are currently developing plans for planetary exploration over the next decade, and if they see the ice giants as the highest priority, then we can be ready. Because the discoveries could be astonishing and they're out there, waiting for us.

Looking back: The Sky at Night

16 November 1957

In the episode of *The Sky at Night* screened on 16 November 1957, Patrick Moore looked at what was set to become a new space-based tourist attraction located in central London. On Marylebone Road, next door to Madame Tussauds, the London Planetarium was preparing to open its doors in March 1958, becoming the first planetarium in the UK.

The auditorium was capable of seating over 300 people, who watched shows projected onto the 18m-wide dome above. For the first 40 years of operation, a mechanical star projector showed a view of the night sky as seen from Earth, with the aim of bringing the wonders of the night sky to the heart of a heavily light-polluted city.

▲ Images of the night sky were projected on the inside of the Planetarium's dome

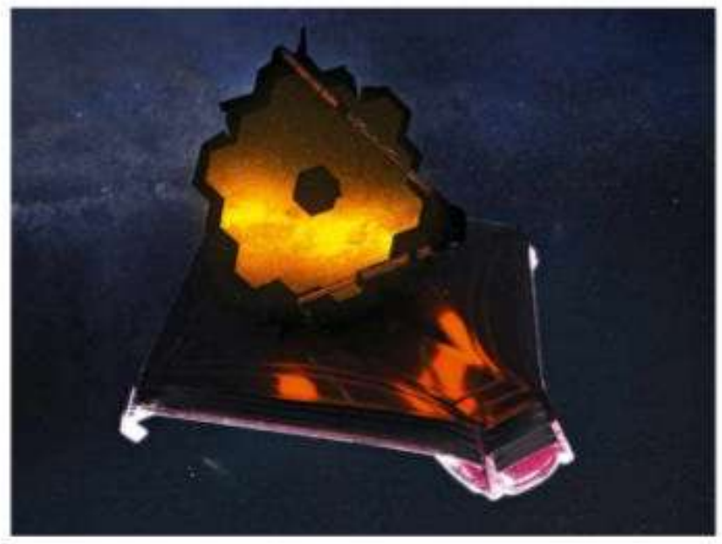
As time and technology progressed, the Planetarium moved to keep up. Laser light performances were added in the late 1970s, then in 1995 a new digital planetarium system – Digistar II – was installed, allowing for complex new programmes rendered in 3D. Rather than just looking at stars from a distance, the show could swoop over planetary surfaces or skim past distant nebulae.

But despite a second projector upgrade in 2004, the Planetarium's days were numbered. In 2006, Madame Tussauds ceased running astronomical shows, leaving the Peter Harrison Planetarium at the Royal Observatory Greenwich as the home of London's only planetarium.

Looking ahead to the JWST

As the much-anticipated James Webb Space Telescope (JWST) nears its launch date, Maggie and Chris look back at some of the incredible telescopes throughout history that have redefined our understanding of the cosmos. The team also looks at how the JWST could enable astronomers to unravel some of the biggest secrets in the Universe.

BBC Four, **14 November**, 10pm (first repeat BBC Four, **17 November**, 7:30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information



▲ The 6.5m James Webb Telescope will be the largest ever launched into space

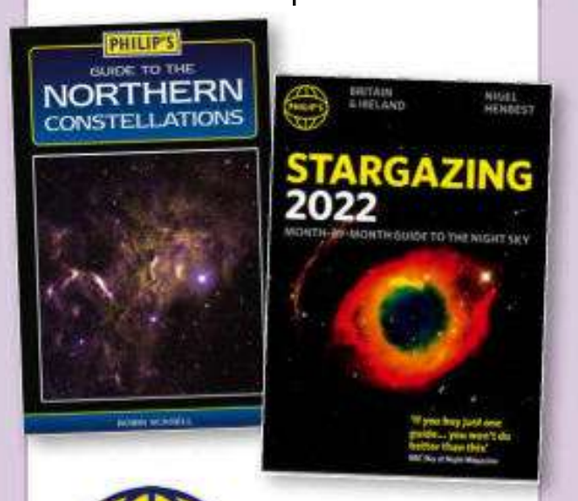
Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize:
two Philip's titles



The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2022* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

Under darker skies

I recently went on an astro camping trip along with the Northolt Branch Observatories Facebook group. It was my first time camping and the first taking my full deep-sky object setup away from home. We picked a campsite away from London towards Hastings, in a Bortle 4 location [the Bortle scale being a measurement of dark skies]. The weather wasn't perfect, but in the clear spells between the hazy clouds there were spectacular skies. I saw the Andromeda Galaxy, M31, with the naked eye for the first time and you could see its entire width.

During the night I managed to get one single shot of M31 before the clouds rolled back. I was shocked and amazed to see the result, compared to the results back home. It looked like the single RAW image was the same as a stacked 2–3 hours, stretched image from home. When I got back I decided to compare the two. The top is under Bortle 4 skies and the bottom under Bortle 8 at home. Both were taken with the same camera and settings. I am somewhat shocked by the result! **Darshna Ladva, London**

Darsha's images of M31 from dark (top) and city skies

What a valuable insight, Darsha. The comparison really illustrates what light pollution does to our view of the night sky, and the value of escaping to a dark-sky location if you don't live in one. Sadly it's an experience many of us will be all too familiar with. – *Ed.*

Tweet

Joanna 📷
@Joeynoble • Sep 23
A bit of stargazing this evening, while doing a bit of research. I can't help but love the colours of our night sky, even in the massively light-polluted Black Country! @OlympusUK #startrail #livecomp #BlackCountry #NightSky @skyatnightmag #Kingswinford @WeAreBCR

Bobby's snap of the Moon, and Balderick

Harvest delight

While looking after a smallholding for some friends, my wife Myra and I had one of the most enjoyable nights of observing ever. Two nights before the full Harvest Moon, armed with my Bresser 15x70 astronomical binoculars and a smartphone, we were thrilled when we observed the waxing gibbous Harvest Moon, Jupiter, Cassiopeia, and many other wonders of the night sky. We were also joined by Bob and Balderick, the two resident cats, who brought home to us that while observing, we have the opportunity to bond with nature, as other readers of *Sky at Night Magazine* have commented on previously.

Bobby Ayre, via email

How high the Moon

Something about the Moon has been on my mind for months. To illustrate, here are two photos; I took the first back at 8:04pm on 25 April and the other at 8:05pm on 26 April, 24 hours later. The thing that has puzzled me ever since is why the Moon was so much higher in the sky on the 25th than it was on the 26th, and what causes such a difference in such a short space of time? Sorry to

Within the space of 24 hours, Geoff's images show how the Moon appears at different heights, at 8:04pm on 25 April (top) and at 8:05pm (below) on 26 April

trouble you with what may seem a simple thing, but I'm very intrigued.
Geoff Stainer, via email

Great question, Geoff! The thing that causes the Moon to be in a different part of the sky at the same time each night is that at the same time as Earth is rotating on its axis every 24 hours, the Moon is also moving more slowly in orbit around Earth, which it takes 27.3 days to complete. ***– Ed.***

In a spin

I was lucky enough to ask the question, "Do black holes spin?" on *The Sky at Night*'s 'Question Time' episode, filmed in Chelmsford. Chris Lintott answered yes, and explained about the way that the gravitational effect of the spinning black hole caused the matter being captured to rotate around it as it nears the event horizon (in my words, like water going round a plug hole, before reaching the point of no ▸

ON FACEBOOK

WE ASKED: What are your favourite astronomy jokes?

Tony Healey A galaxy walks into a bar and orders a drink. The bartender says 'sorry I can't serve you, you're barred'.

David Greensmith Because of all the sniggering from tonight's planet watch participants, instead of looking at Uranus we're going to have a peek at Mars.

Gemma Brown "Orion's Belt is a big waist of space." Terrible joke – only three stars.

Lucas Borkowski A joke from the Cold War period: the USSR painted the Moon red to show its dominance in space, and then the Americans wrote Coca-Cola on it with white paint.

Martin Coule I went to a pub on the Moon. It was okay, but it had no atmosphere.

Carol Miller How did the Moon know it had had enough to eat? It was full.

Kriss Jupiter What do aliens listen to? Neptunes.

Colin Ackerley What do you do if you see a space man? Park in it man.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I'm turning my 10-inch Dobsonian into a Go-To scope and thinking of using an HEQ5 Pro mount, but what mount would you recommend?

DEAN COATES

A 10-inch Dobsonian reflector would make an excellent telescope for conversion to equatorial Go-To use, for both observing and imaging. However, assuming that your telescope is of a standard metal construction, it will weigh around 11kg without accessories like a finderscope and eyepieces for observing, or a camera and guidescope for imaging, so it will require a substantial mount to support it properly. The HEQ5 Pro would be operating above its recommended limit for astrophotography and a couple of kilograms under its maximum for observing. Taking into account additional external influences like the effect of shaking by the wind, the time it takes for vibrations to dampen down after focusing and so on, so this would not be the best mount choice for this scope.

▲ A mount like a Sky-Watcher NEQ6 Pro will support a higher payload

A Sky-Watcher NEQ6 Pro or EQ6-R Pro would be a more suitable mount as they have a higher payload allowance, and alternatives like the iOptron CEM 40 should also be on your shortlist. Don't forget to factor in the cost of a pair of suitable tube rings and a dovetail bar when pricing up your investment.

Steve's top tip

What is a diagonal for?

When you observe through a refractor or Cassegrain telescope the eyepiece gets lower and lower as you increase the altitude at which you are observing, until it becomes very uncomfortable to view straight through the telescope. However, you can use a diagonal to change the viewing angle. A diagonal is a triangular attachment with a small mirror set at 45°, which fits in the focuser and bends the light collected by the telescope through 90° to project it into the eyepiece. This simple attachment makes it easier to observe through the scope as you can view down into it rather than up into it.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

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▸ return and going down the drain).

After the show I thought further... if the theory is true that every galaxy has a black hole at its centre driving the dynamics of the matter it captures in its gravitational field, why are all galaxies not spiral in formation? So, if a black hole was static would matter still spin around it, or is it the spin of a black hole that produces this effect? Consequently, if a black hole doesn't spin, does this account for non-spiral galaxies or are there other contributing factors?
Stephen Piper, via email

Heading to space

I loved your online story about women in space (**www.skyatnightmagazine.com/space-missions/women-astronauts**). Well, a NASA study does reveal that we're better suited for space travel! Now that space travel is becoming more accessible, I got inspired to build a tool to help you prepare for your own expedition. I teamed up with a fellow PhD candidate in physics, and we built the Space Travel Calculator (**www.omnicalculator.com/physics/space-travel**). It lets you calculate how much time and fuel it will take to travel to a certain astronomical destination. It includes Solar System and interstellar destinations, plus some from *Star Trek*! I hope this will get other readers exploring the wonders of space from home.
Purnima Singh, via email

Instagram
sloopjohnd82 • 13 September
I lost count of all the times I had driven past the Lovell Telescope and promised myself to get a picture next time. Finally, it happened! Anyway, I think I much prefer it in colour to black and white. #cheshire #telescope #jodrellbank #jodrellbankobservatory #astronomy #lovelltelescope @bbcskyatnightmag @jodrellbank @visitchesterandcheshire @visitengland

SOCIETY IN FOCUS

Weymouth Astronomy Club meets on the South Coast on the second Friday of the month (except August). We are a friendly bunch with a wide range of astronomical interests. Some prefer practical observing and astrophotography, while others get stuck into the theoretical aspects of the night sky. Overall, however, the club has a good pedigree of helping those just beginning their astronomical journey and guiding them through what there is to discover in the heavens above.

We have a varied programme and our visiting speakers always bring expertise to our meetings, enabling members to deepen their knowledge of astronomy. Besides our monthly meetings, we hold viewing nights timed to coincide with special astronomical events, and arrange visits to places of interest like Sidmouth's Norman Lockyer Observatory. We have also held public viewing events in association with the Sandsfoot Castle and Rodwell Trail Trust, which have been well attended by

▲ Weymouth Astronomy Club members during a pre-pandemic public open night

people from across the area interested to learn more about observing the night sky.

Throughout the COVID-19 pandemic Weymouth Astronomy Club has remained active, using online technology to deliver our monthly meetings. We expect to use both face to face and online meetings to deliver our programme for the future.

To find out more about Weymouth Astronomy Club, come along to one of our meetings at St Aldhelm's Church, Spa Rd, Weymouth, or visit our website.
John MacDonald, Chair, Weymouth Astronomy Club
▸ www.weymouthastronomy.co.uk

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

Live Haw Wood Farm Astronomers' Week

Saxmundham, Suffolk, 1–8 November

Enjoy a week of stargazing and astrophotography at Haw Wood Farm, a designated Dark Sky Discovery Site. The camp pitches are £12 per night and you can book by phone (01502 359550) or email (**info@hawwoodfarm.co.uk**).

Live Is Anybody There?

Grindon Parish Hall, Thorpe Thewles, North Yorkshire, 10 December, 7:30pm

Cleveland and Darlington Astronomical Society hosts David Ettie's talk on the question of intelligent life elsewhere in the Universe, and the risk that aliens may be as unpleasant as humans! New members welcome. **www.cadas-astro.org.uk**

Live Stargazing evenings

Observatory Science Centre, Herstmonceux, East Sussex, 12 and 27 November, 6:30pm and 11pm

Come and look at some exciting night sky objects through some of the largest telescopes in the country. Other activities will be scheduled if the weather is cloudy. Tickets are £8.75 for adults and £6.75 for children. **www.the-observatory.org**

Live Life After Skylark

Torquay Boys' Grammar School, Devon, 18 November, 7:30pm

Torbay Astronomical Society hosts Roger D Cooper, former senior experimental officer with the University of Leicester Space Research Group, for his talk on Skylark, the British sounding rocket project that operated from 1957 to 2005.

DAVID MURTON, SARAVUTVANSET/ISTOCK/GETTY IMAGES

PICK OF THE MONTH

▲ **If you're looking to get into astro imaging, this could be the ideal course for you**

Introduction to Astrophotography

Learn how to capture the night sky with expert tips on getting started, from 1 November

If you've ever admired beautiful images of galaxies, nebulae, planets and stars, and wondered how to capture them yourself, get started with the Royal Observatory Greenwich's Introduction to Astrophotography course. Classes cover basic knowledge and techniques, from camera settings to processing, and also touch on using telescopes and guiding for deep-sky photography.

Taught every Monday, 7–9pm via Zoom, the course runs for six weeks from 1 November. It costs £96 and you can book places at **bit.ly/3Aulhaa**.

Non-members are welcome: £3 for adults, £1 for under 18s. **torbayastro.org.uk**

Online Binoculars talk

26 November, 8pm

All are welcome to Mid-Kent Astronomical Society's Zoom talk where Steve Tonkin gives a guide to different binocular types and buying pitfalls to avoid. Non-members £3; contact **membersec@midkentastro.org.uk** (36 hours ahead) to join the talk.

Live Chesterfield stargazing

Chesterfield Observatory, East Midlands, Fridays during November, 8pm

View the night sky through Chesterfield's huge 18-inch telescope. Non-members welcome on Fridays: £2 adults; under 16s are free. **chesterfield-observatory.co.uk**

Live Lights Out for Our Darker Skies Exhibition

PK Porthcurno museum, Cornwall, until 31 December

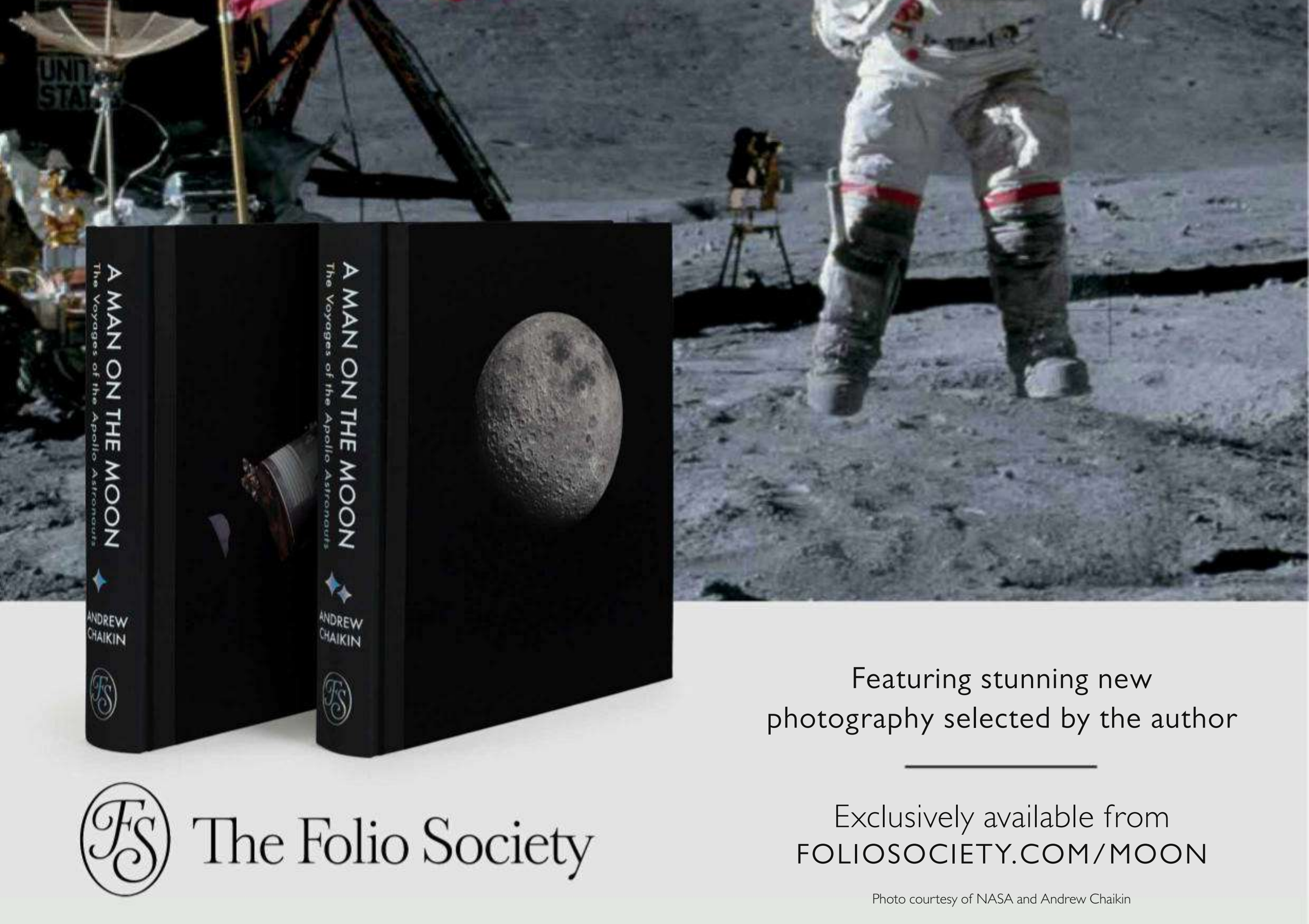
This exhibition – part of a push for International Dark Sky status for the West Penwith peninsula – explores the issues of light pollution and celebrates dark night skies. Expect astrophotography, films and art by local artists. **pkporthcurno.com**

A MAN ON THE MOON

The Voyages of the Apollo Astronauts

ANDREW CHAIKIN

NEW PREFACE BY THE AUTHOR
FOREWORD BY TOM HANKS



The Folio Society

Featuring stunning new
photography selected by the author

Exclusively available from
FOLIOSOCIETY.COM/MOON

Photo courtesy of NASA and Andrew Chaikin

The amateur astronomer's forum

FIELD OF VIEW

Space inventions that didn't quite take off

An airship on Venus? **Jonathan Powell** looks at space travel's stranger concepts

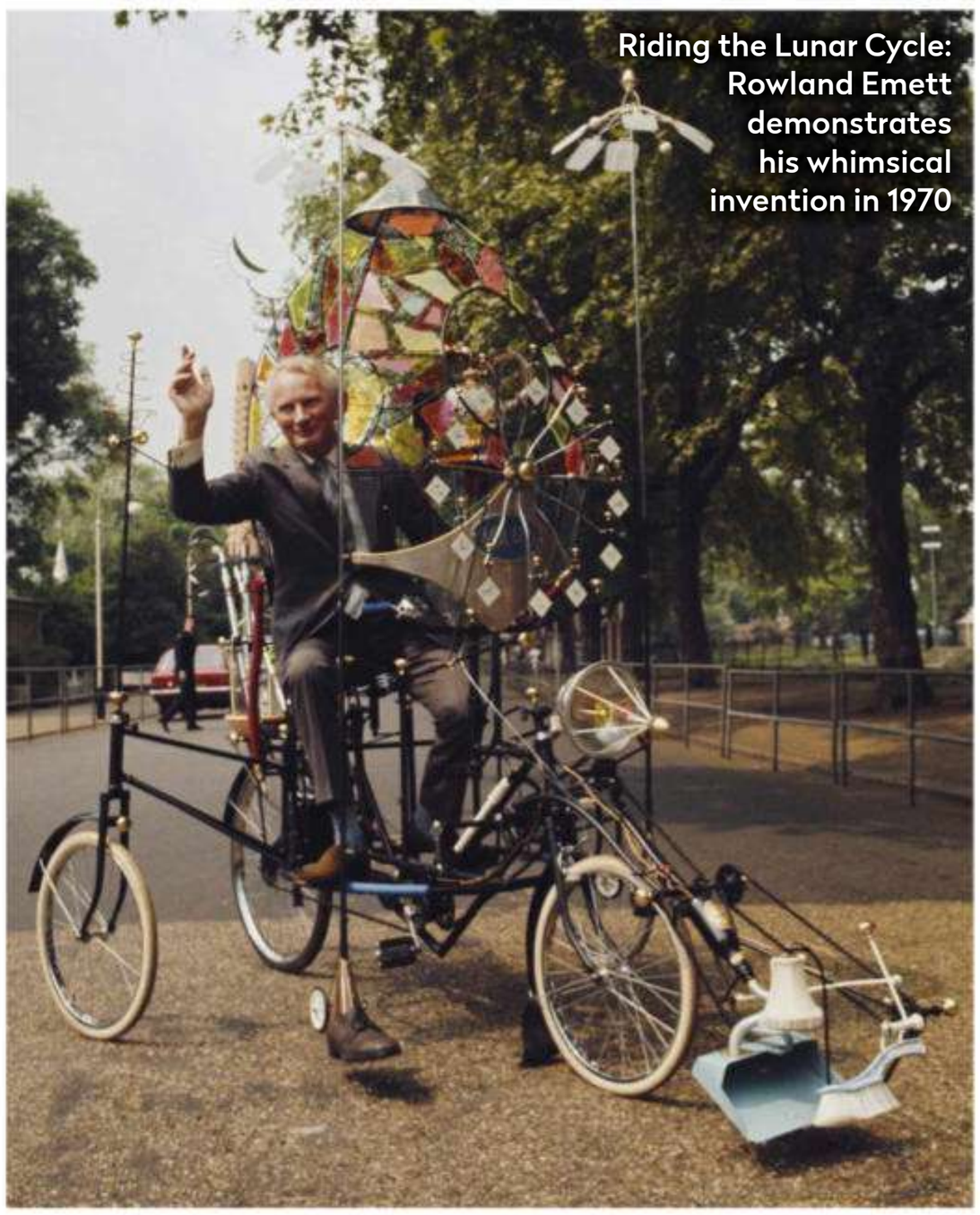
The saying that 'necessity is the mother of invention' is known to us all, and there have been many great ideas spawned in eureka moments. However, aside from *Back to the Future*'s ingenious flux capacitor, there have and will continue to be some clever concepts that never saw their true potential, and the filing cabinet on space orientated ideas is bulging at the seams.

Let's take the 'space elevator' (pun intended). This idea was first explored by Arthur C Clarke in his 1979 novel *The Fountains of Paradise*, where he envisaged a mammoth tower reaching into space. The plan was to reach beyond the gravitational pull of Earth, thus via the space elevator enabling material and supplies to be delivered some 36,000km up in geosynchronous orbit.

The space elevator, along with the parallel idea of the 'spaceline' – which proposed a tethered cable from the surface of the Moon back to Earth's atmosphere – certainly carries merit. However, the International Space Station, along with humankind's passion to blast stuff from the ground upwards, have over time negated a need to develop such inventions.

Then there's the 'space gun', or 'Verne gun' (after novelist Jules Verne's fictional firing structure), powering craft into space almost cannon-style, but with no circus-style safety net. This concept gained serious attention for a time, particularly under America's Project HARP (High Altitude Research Project) and its Martlet series of tests in the early 1960s, but the idea never really took off.

The 'StarTram' idea is not yet a dead duck but remains questionable. The system, probably situated on a high mountain summit, would use magnetic levitation (or maglev) where two sets of magnets repel and push equally to force the object forward. One can imagine it as rather like quickly squeezing a tomato down a hosepipe but without the tomato touching the sides.



Riding the Lunar Cycle: Rowland Emett demonstrates his whimsical invention in 1970

With the US Space Shuttle having commanded the skies, one feels somewhat sad for the Soviet version that was created as potential competition. BURAN, meaning 'blizzard', was built and tested but that's as far as the project went.

The questionable High-Altitude Venus Operational Concept (HAVOC) is an idea intended to send piloted, helium-filled airships cruising through the Venusian atmosphere. One can predict that astronaut crew applicants will be thin on the ground on recruitment day.

However, in order to properly appreciate the whole notion of the invention properly, one must look at the inventor: not the large corporations but the lone individual – an individual with a wonderfully creative mind, someone who really is out there!

Look no further than British inventor Rowland Emett OBE (1906–90) and his incredible Lunar Cycle, which upon inspection deserves the highest of praise. With its moving dustpan and brush to sweep up Moon dust, a cheese comparator unit to check the composition of comestibles supposedly located on the dark side of the Moon, and a cat to chase off the lunar mice, Emmet's invention would certainly have enhanced NASA's Apollo technology after the "One small step for man...." event in 1969. It is Rowland Emmett and his kindred spirit that encapsulate the true sense of the word 'inventing'... and long may it continue.

Jonathan Powell is a freelance writer and broadcaster. A former correspondent at BBC Radio Wales, he has written three books on astronomy and is currently astronomy columnist at the *South Wales Argus*

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BBC Sky at Night MAGAZINE

SPARKLERS AND SPARKLING STARS

Stargazing on Bonfire Night

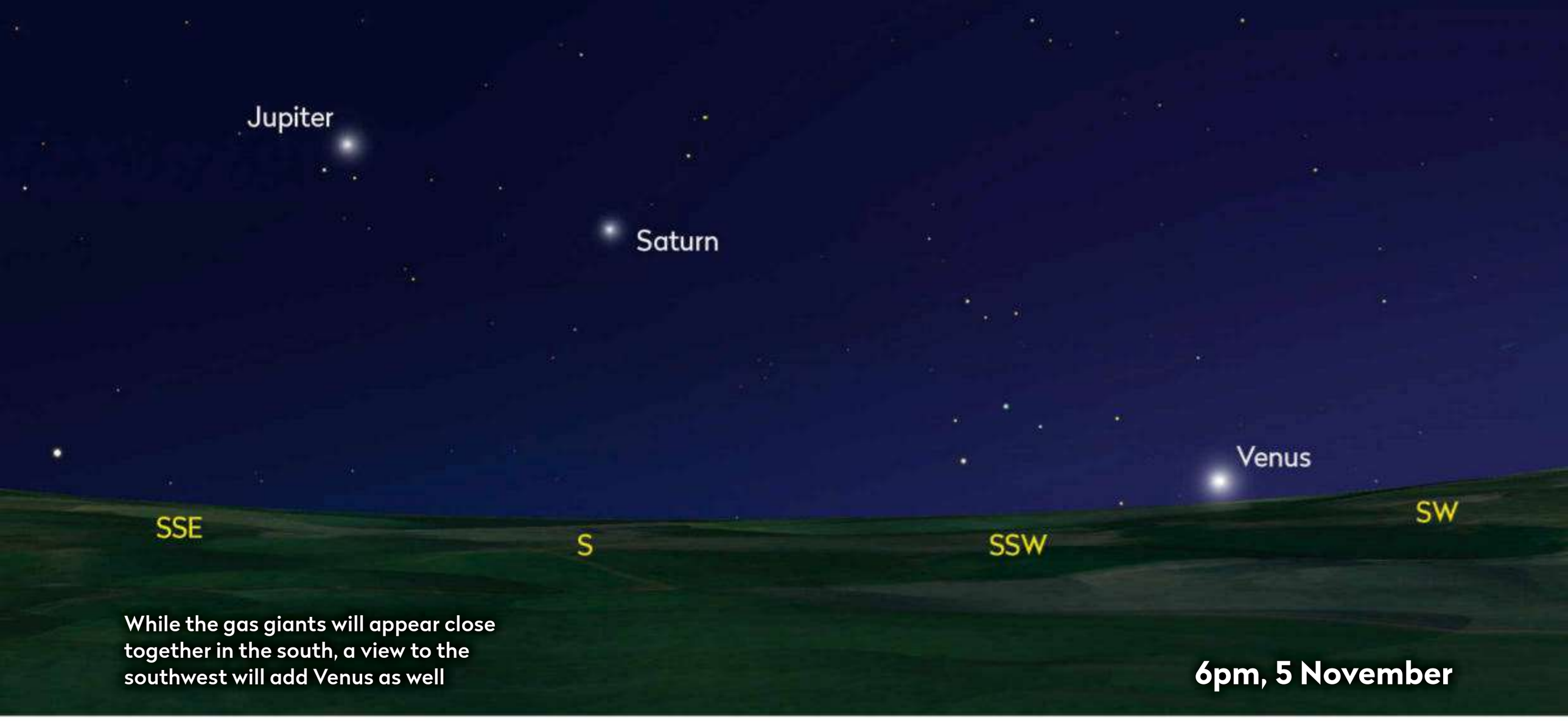
Follow **Stuart Atkinson's** naked-eye tour and take in an extra stellar show while you watch the fireworks

There's one night every year when it's guaranteed that people will be lured away from their TVs and out into the darkness, and that's 5 November – Bonfire Night. As darkness falls some families head into their gardens to light a handful of fireworks, while others join the crowds in parks or sports grounds to bask in the glow of a bonfire and watch a large display. This year might be different due to COVID-19, but not even a global pandemic will stop us standing in a field for an hour or so and "oohing" and "aahing" at the sight of rockets exploding in cascades of colour.

But watching fireworks is seeing only half of the display available because, as we'll show here, if the sky is clear on Bonfire Night there are many other beautiful things to see in the night sky too, and during lulls in the action you just have to raise your eyes to enjoy seeing some celestial wonders. Here's what to watch out for as the evening progresses. ▸

BRIGHTSTARS/ISTOCK/GETTY IMAGES, MJ_PROTOTYPE/ISTOCK/GETTY IMAGES

Bonfire Night brings many potential stargazers out of the comfort of their homes to gaze skywards



While the gas giants will appear close together in the south, a view to the southwest will add Venus as well

6pm, 5 November

6pm: Jupiter, Saturn and Venus

As the evening news programmes begin on TV it will be a sign that it's time to pull on your jacket, gloves and bobble hats and head outside. With the first fireworks of the evening crackling up into the sky, you'll see two bright stars shining close together low in the south. These are actually the planets **Jupiter** and **Saturn**, currently appearing close together in the sky, but actually separated in space – and from us – by enormous distances. Jupiter, on the left and the brighter of the two, is the largest world in our Solar System, a bloated ball of gases and liquids so huge it could swallow 1,000 Earths with room to spare. NASA's Juno space probe is sending back breathtaking images of Jupiter's swirling cloud belts and psychedelic-looking storm systems, all of which are available to view online for free (visit **nasa.gov/mission_pages/juno/images**). Looking like a yellow-hued star to blue-white Jupiter's lower right, fainter Saturn is, of course, famous for its rings, but these can only be seen through a telescope.

With binoculars you can see Jupiter and its four Galilean moons

If you have a clear view to the southwest you might be able to see another planet. **Venus** will be shining very low in the sky in that direction, a Bonfire Night 'Evening Star', but just be aware that any trees or houses on your skyline in that direction will hide it from your view.

Fireworks and fiery stars

How do they each get their beautiful colours?

The colours of the stars are dictated by their hot surface temperatures. Red stars, like Betelgeuse are around 3,500°C, and these are cooler than yellow stars like our Sun (6,000°C), which in turn are cooler than white or blue stars, like Rigel (10,000°C).

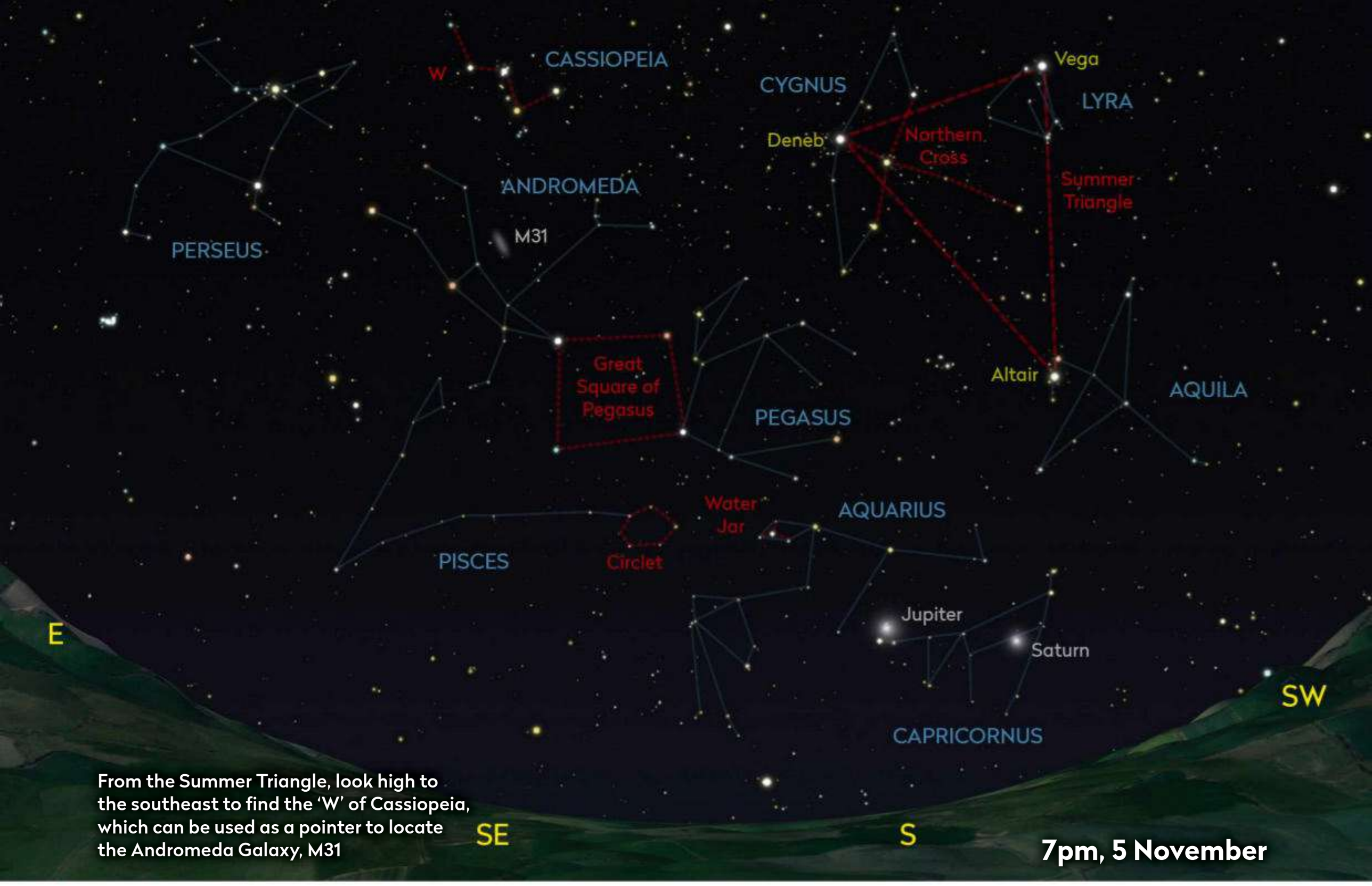
The colours of fireworks are caused by burning different chemicals. For example, reds are produced by strontium, hot oranges by calcium, yellows by sodium and cerulean blues by copper. And because all these things were created during the birth of the Sun, they are directly connected to astronomy!

CHARTS BY PETE LAWRENCE, CLAUDIODIVIZIA/ISTOCK/GETTY IMAGES, CHARLES BADEN/ISTOCK/GETTY IMAGES, DAVIDHAJNAL/ISTOCK/GETTY IMAGES

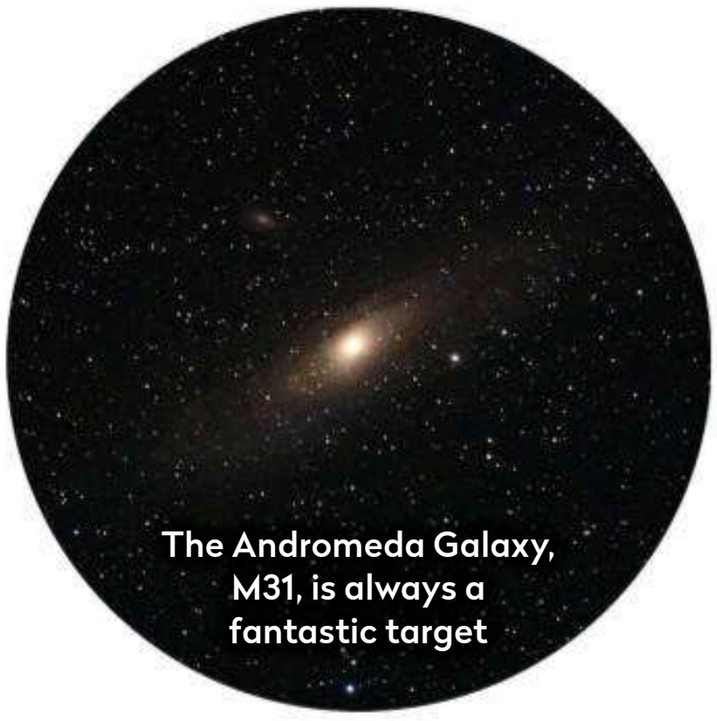
7pm: The Summer Triangle, Cassiopeia, the Andromeda Galaxy and the Milky Way

By now your eyes will have 'dark adapted' enough that even with the red glare of rockets bursting in the air above your head you'll be able to see more things in the night sky. One of the first you'll notice is a striking triangle of three bright blue-white stars almost directly above Jupiter and Saturn. This isn't a constellation, it's an asterism – an obvious pattern of stars – called the **Summer Triangle**, still visible even though it's November. Its three stars are **Deneb** (Alpha (α) Cygni), **Vega** (Alpha (α) Lyrae) and **Altair** (Alpha (α) Aquilae), the brightest stars in the constellations of **Cygnus, the Swan**, **Lyra, the Lyre** and **Aquila, the Eagle**, respectively. Having found the Summer Triangle, look high to the southeast and you'll spot a '**W**' of stars. This is the constellation of **Cassiopeia, the Queen**, and you can use it as a pointer to help you locate something very special indeed – **M31, the Andromeda Galaxy**.

M31 is a group of billions and billions of stars, so far away their faint light has taken

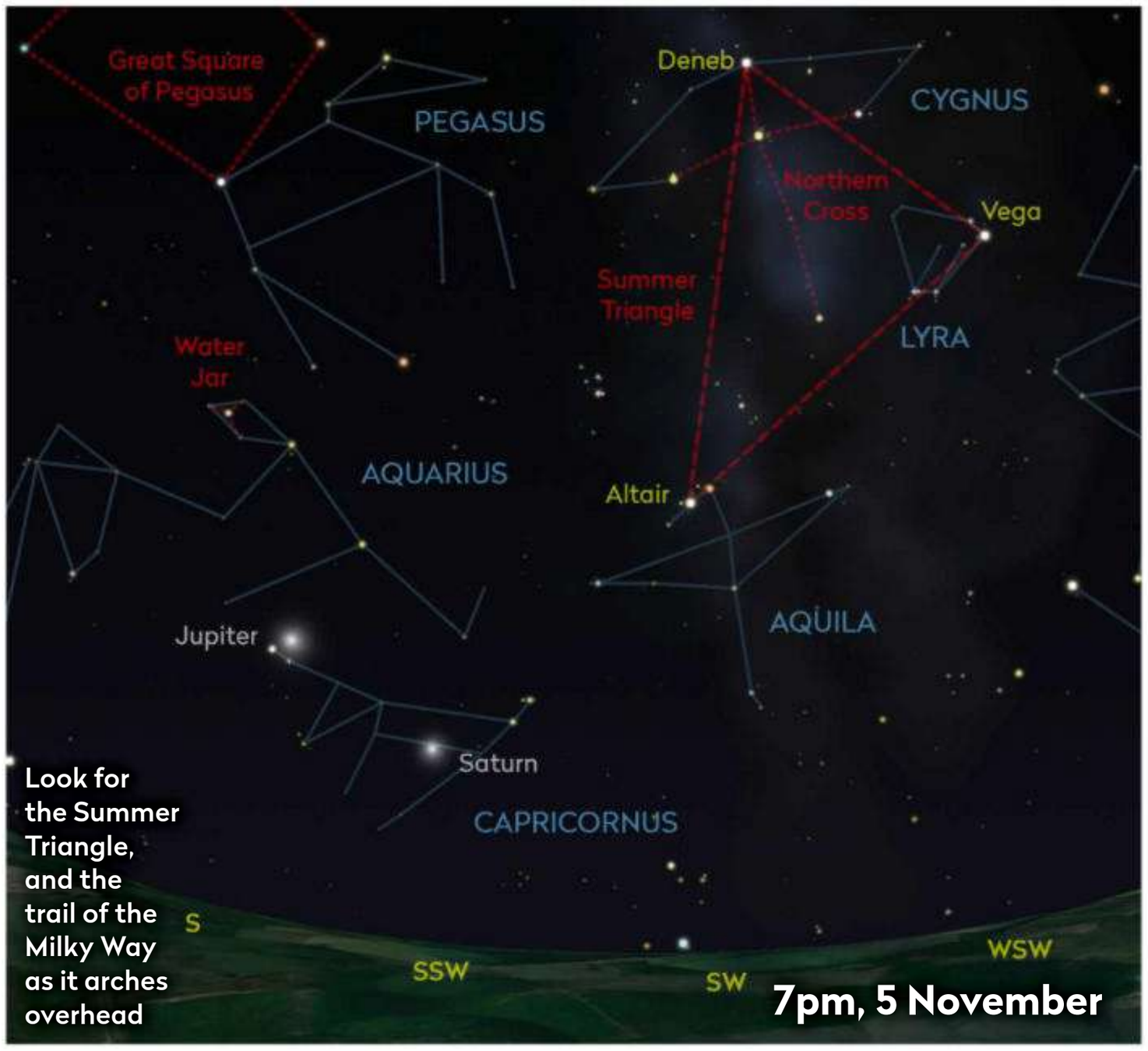


From the Summer Triangle, look high to the southeast to find the 'W' of Cassiopeia, which can be used as a pointer to locate the Andromeda Galaxy, M31



The Andromeda Galaxy, M31, is always a fantastic target

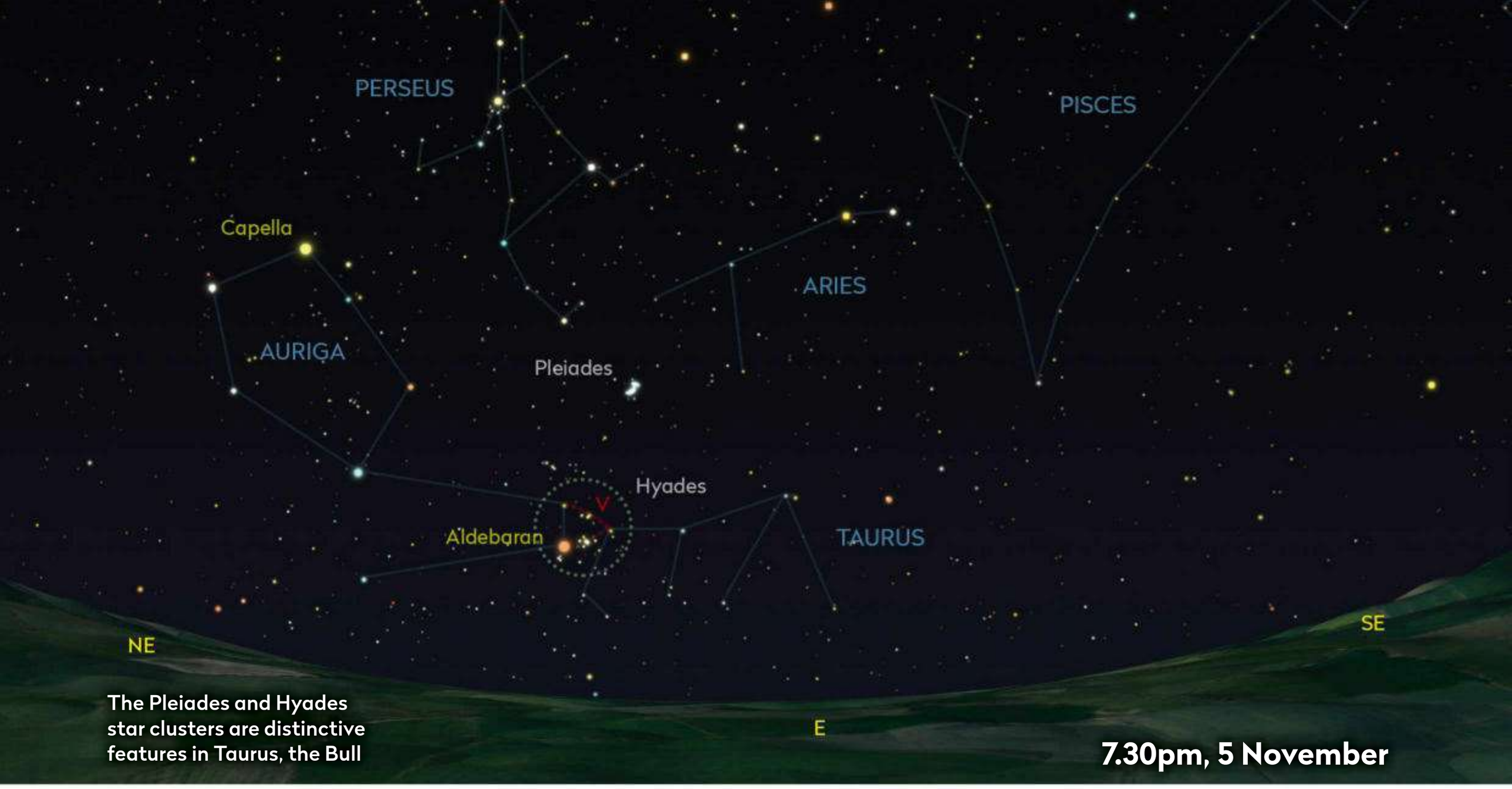
The 'W' shape of Cassiopeia should be easy to spot



Look for the Summer Triangle, and the trail of the Milky Way as it arches overhead

more than two million years to reach us. Long exposure photos taken through telescopes reveal M31 to be a lens-shaped cloud of glittering stars streaked with dark dust lanes, but to the naked eye it looks like a small smudge. In fact, if your Bonfire Night sky is smoky you might need a pair of binoculars to see it, but as with many astronomical objects it's knowing what that smudge is that makes seeing it so exciting.

If your sky is clear, and if you aren't surrounded by light pollution, you might also glimpse the misty trail of the **Milky Way** rising up from the western horizon. Arching overhead, this is the combined light of billions of stars within our own Galaxy, seen from within, and as you look at it you might even be reminded of smoke rising from a distant bonfire... ▸

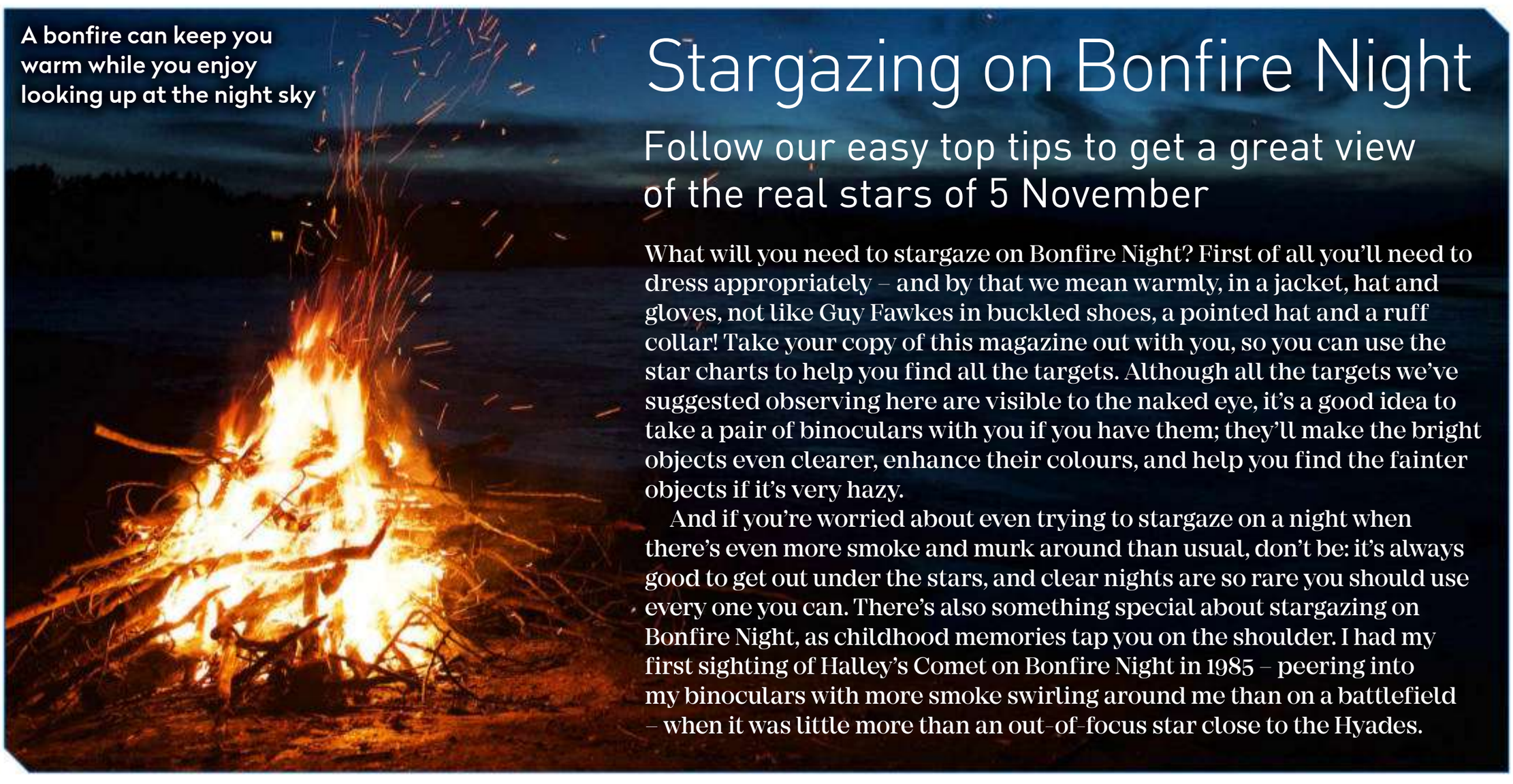


The Pleiades and Hyades star clusters are distinctive features in Taurus, the Bull

7.30pm, 5 November

7.30pm: Taurus charging – the Pleiades and Hyades star clusters

By mid-evening the constellation of **Taurus, the Bull** will be rising in the east. It's easy to spot because it is dominated by two striking star clusters that are both obvious to the naked eye. The most noticeable is the **Pleiades** star cluster. Look to the east mid-evening and you'll see a small knot of ice-blue stars shining low in the eastern sky, perhaps the size of your thumbnail held out at arm's length – that's the Pleiades. This celestial celebrity of a cluster contains hundreds of stars, but it's known widely across the world as 'The Seven Sisters' because its seven brightest members can be seen with the naked eye, looking like a tiny, squashed-up version of the Plough. If you look halfway between the eastern horizon and the Pleiades you'll see a strikingly orange star. This is **Aldebaran** (Alpha (α) Tauri), the 'Eye of the Bull', and if your sky is dark enough you'll see that it marks the end of one side of a 'V' of stars lying on its side. This arrowhead is the **Hyades** star cluster, a favourite of many observers. Much larger than the neighbouring Pleiades, the Hyades represents the horns of Taurus.



A bonfire can keep you warm while you enjoy looking up at the night sky

Stargazing on Bonfire Night

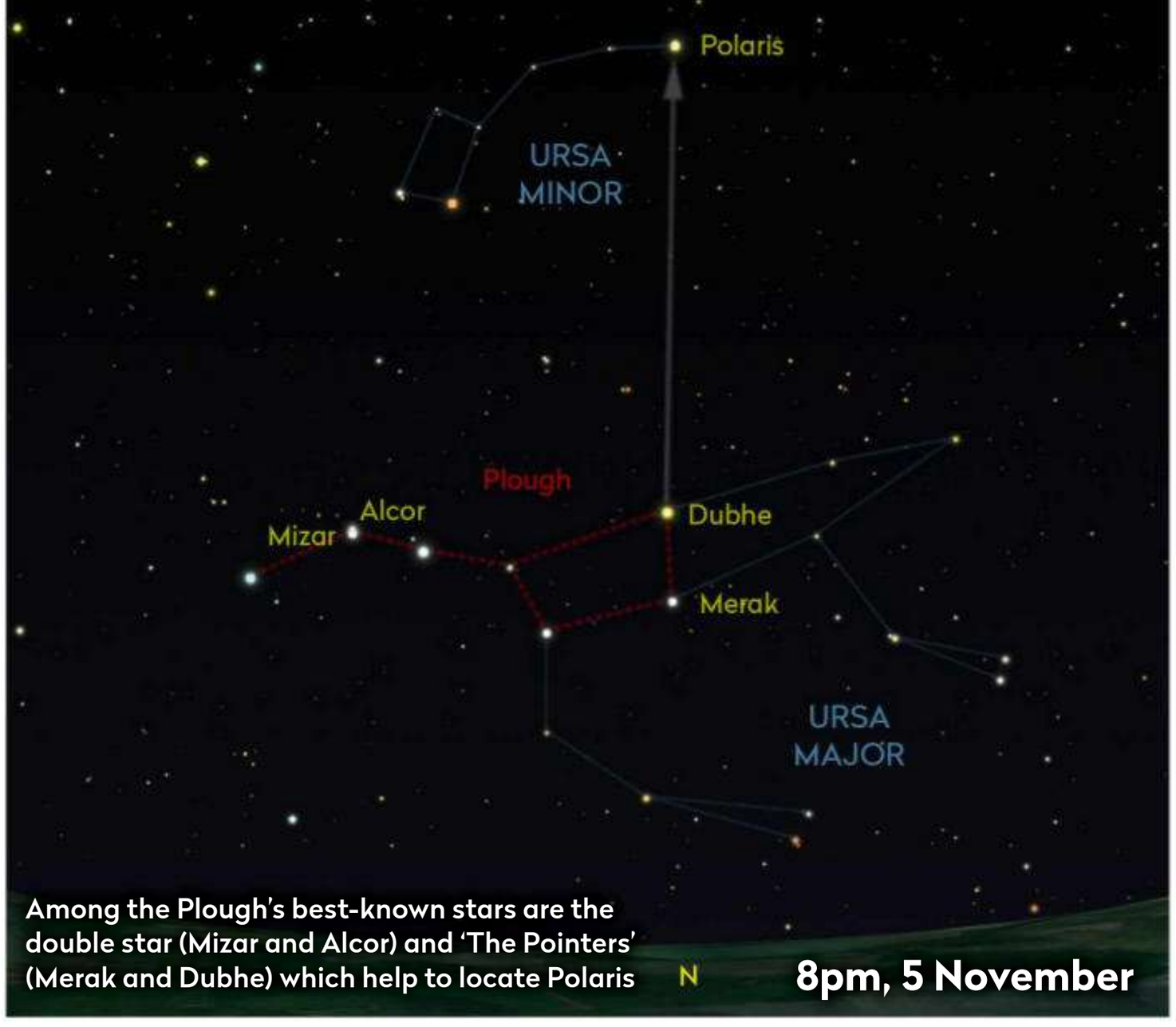
Follow our easy top tips to get a great view of the real stars of 5 November

What will you need to stargaze on Bonfire Night? First of all you'll need to dress appropriately – and by that we mean warmly, in a jacket, hat and gloves, not like Guy Fawkes in buckled shoes, a pointed hat and a ruff collar! Take your copy of this magazine out with you, so you can use the star charts to help you find all the targets. Although all the targets we've suggested observing here are visible to the naked eye, it's a good idea to take a pair of binoculars with you if you have them; they'll make the bright objects even clearer, enhance their colours, and help you find the fainter objects if it's very hazy.

And if you're worried about even trying to stargaze on a night when there's even more smoke and murk around than usual, don't be: it's always good to get out under the stars, and clear nights are so rare you should use every one you can. There's also something special about stargazing on Bonfire Night, as childhood memories tap you on the shoulder. I had my first sighting of Halley's Comet on Bonfire Night in 1985 – peering into my binoculars with more smoke swirling around me than on a battlefield – when it was little more than an out-of-focus star close to the Hyades.

CHARTS BY PETE LAWRENCE, RAMI SALLE/EYEEML/ISTOCK/GETTY IMAGES

8pm: The Plough, Mizar and Alcor, and Polaris



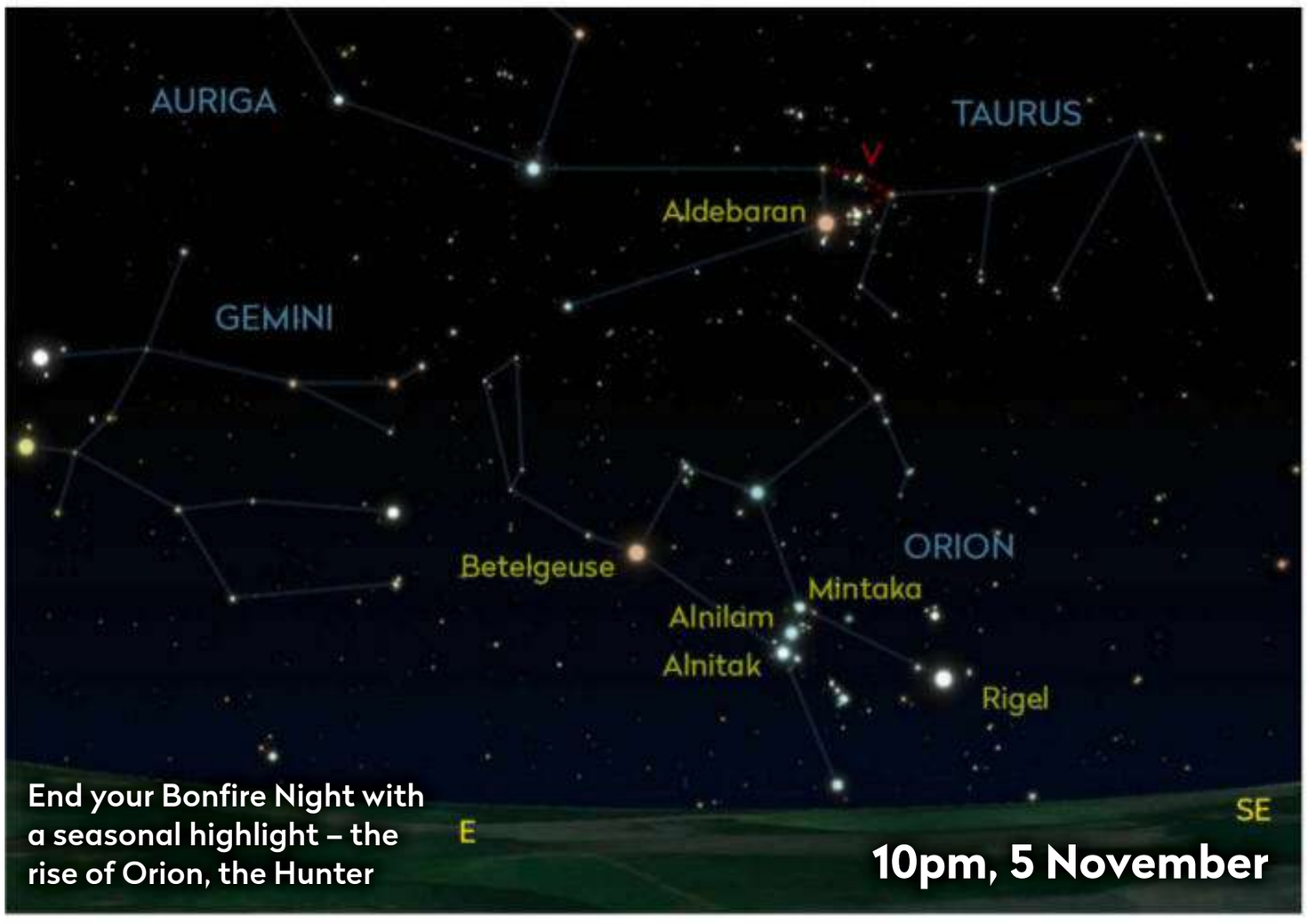
Among the Plough's best-known stars are the double star (Mizar and Alcor) and 'The Pointers' (Merak and Dubhe) which help to locate Polaris

By now the Bonfire Night festivities will be well underway and if you look to the north as the sparkly trails of rockets swoosh up into the sky, you'll see the stars of the **Plough** (or Big Dipper) shining above the horizon. November is a great time of year to see this asterism – which is part of the larger constellation of **Ursa Major, the Great Bear** – because during the evening its orientation means it looks exactly like the famous 'Saucepan' many people affectionately call it.

If you have good eyesight you will be able to see that the star in the middle of the Plough's handle is actually two stars close together. This famous double star consists of **Mizar** (Zeta (ζ) Ursae Majoris) and **Alcor** (80 Ursae Majoris).

The Plough isn't just an attractive asterism though; it can be used to find the most famous star in the sky. Its two right-hand stars known as 'The Pointers' point directly towards **Polaris** (Alpha (α) Ursae Minoris), the Pole Star. Many people grow up believing that the Pole Star is the brightest star in the sky, but it's actually only the 48th brightest! Its fame comes from the fact that it just happens to lie directly in line with Earth's polar axis, so it remains still through the night while every other star, planet and object in the sky appears to whirl around it.

10pm: Noticing the sky has changed, and Orion rising



End your Bonfire Night with a seasonal highlight – the rise of Orion, the Hunter

By late evening the firework displays will be drawing to a close, but before heading back indoors take a last look at the sky. You will notice – perhaps for the first time – that it has changed since you came out: **Jupiter** and **Saturn** have dropped behind the horizon, and the **Summer Triangle** is lower too. The **Plough** isn't parallel to the skyline any more, but has pitched up slightly so it's balancing on the end of its handle. The **Pleiades** and **Hyades** clusters will be higher in the sky too.

Finally, as the smoke of dozens of bonfires begins to clear you'll see a striking pattern of stars rising in the east: **Orion, the Hunter**, with red **Betelgeuse** (Alpha (α) Orionis) shining at his right shoulder and his famous **Belt** of three blue-white ice-chip stars pulled across his waist. Seeing Orion climbing up from behind the eastern horizon late on a chilly autumn night is a sure sign that winter is coming.

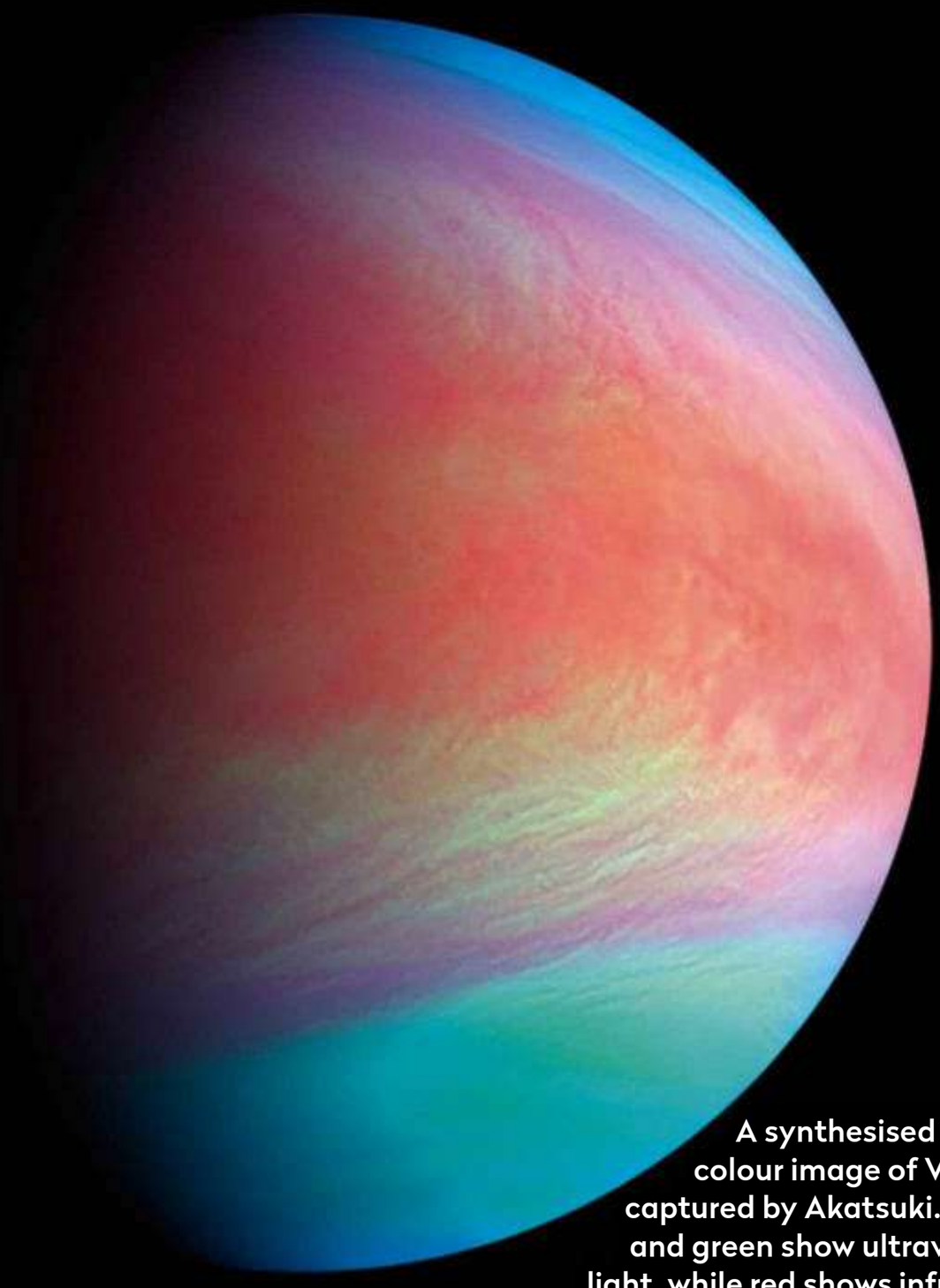
Keep observing

Bonfire Night is popular with many people, because it gives them an opportunity to see coloured lights in the sky, but you may be standing there unaware that Nature is putting on an even more beautiful display of celestial lights – one that takes place every night. For amateur astronomers who can look up and see not just rockets but stars exploding – with misty-armed galaxies turning like Catherine wheels, and shooting stars leaving trails of sparks across the heavens – every night is a cosmic Bonfire Night!

Stuart Atkinson is a lifelong amateur astronomer and author of 11 books on astronomy

Unveiling VENUS

With new scientific discoveries, recent flybys and future missions planned, are we about to finally unlock the secrets of the hellish planet? Planetary scientist **Emily Lakdawalla** explores



A synthesised false colour image of Venus captured by Akatsuki. Blue and green show ultraviolet light, while red shows infrared

JAXA X 5, ESA/NASA/NRL/SOLOHI/PHILLIP HESS, ATMOSPHERES ILLUSTRATION BY PAUL WOOTTON

Venus is in the hot seat this year: NASA and ESA recently announced three new missions to our nearest planetary neighbour, and another two have just flown past on their way to different destinations. Back in August, ESA's Solar Orbiter and the ESA-JAXA collaboration, BepiColombo, performed gravity-assist flybys, marking the first time since 1985 that three spacecraft have made in-situ scientific observations at Venus at the same time. (The third, JAXA's Akatsuki, has been in orbit since December 2015.)

Solar Orbiter is, obviously, a mission to study the Sun, not planets, so most of its cameras are useless at Venus. Most of BepiColombo's sensitive cameras can't see space during its long cruise to Mercury. But both spacecraft carry large suites of instruments designed to measure the intensity and direction of magnetic fields and other instruments that count the number and energy of charged particles (electrons, ions and larger particles). BepiColombo also carries an accelerometer that measures variations in the force of gravity as the spacecraft flies across a planet, giving clues to the composition of its interior.

Across the bow

Venus doesn't have its own magnetic field, but the Sun induces one. As the solar wind streams outwards Venus's field cuts a bow shock into it, similar to the wake from a speedboat. Both BepiColombo and Solar Orbiter approached Venus from within Venus's 'wake', crossing over the bow shock near the time of closest

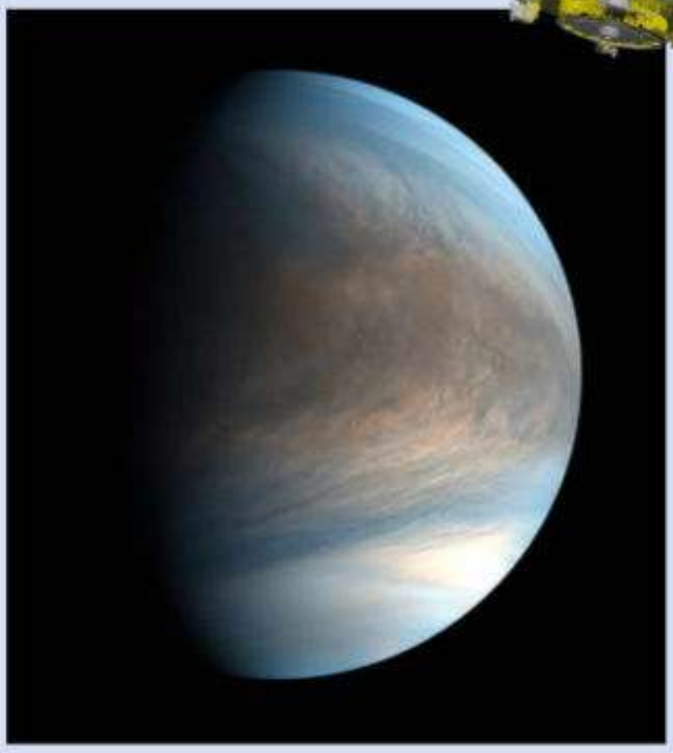
Action, Akatsuki!

Japan's probe is exploring Venus's atmosphere and producing valuable images along the way

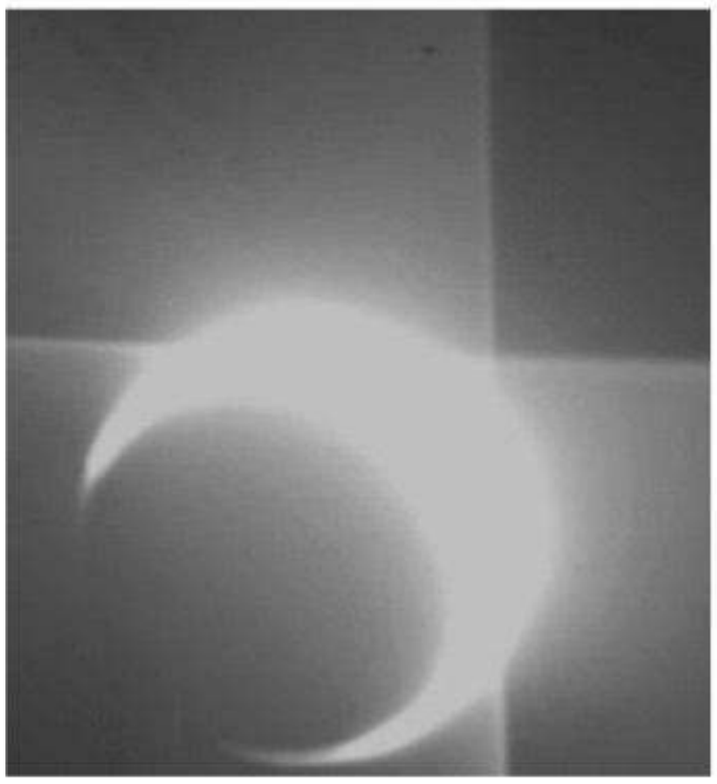
Akatsuki's (see inset) infrared camera IR2 could see the warmth emanating from the clear air under Venus's clouds at night. In this image, Venus's nightside is at left (the dayside was too bright and has been masked). Brighter areas show where the lowest cloud decks are thick; in darker regions, the camera can 'see' more clear air, but not all the way to the surface.

Akatsuki's Ultraviolet Imager (UVI) sees Venus's uppermost clouds, made of drops of sulphuric acid. The dark streaks betray the presence of an unknown chemical that scientists call an 'ultraviolet absorber'.

Perhaps EnVision will identify it. At the altitude of the clouds seen here, Venus's atmosphere rotates around the planet once every four days.



▲ BepiColombo snapped this image as it hurtled past Venus on its way to Mercury



▲ Solar Orbiter captured a gleaming view of Venus during its flyby in August 2021

approach. Solar Orbiter travelled the path 33 hours before BepiColombo. Having three different spacecraft travelling across large swaths of the magnetic field at the same time in different positions will have produced a rich set of science data and will help ESA plan its future EnVision mission to the planet (due to launch in the 2030s).

The two spacecraft passed by Venus on different sides. The result was an acceleration of Solar Orbiter, speeding it on towards a November flyby of Earth and the beginning of its science mission. BepiColombo lost speed, dropping it closer to the Sun. It was due to meet Mercury in October this year, the first of six flybys before it gets captured on the seventh meeting in December 2025.

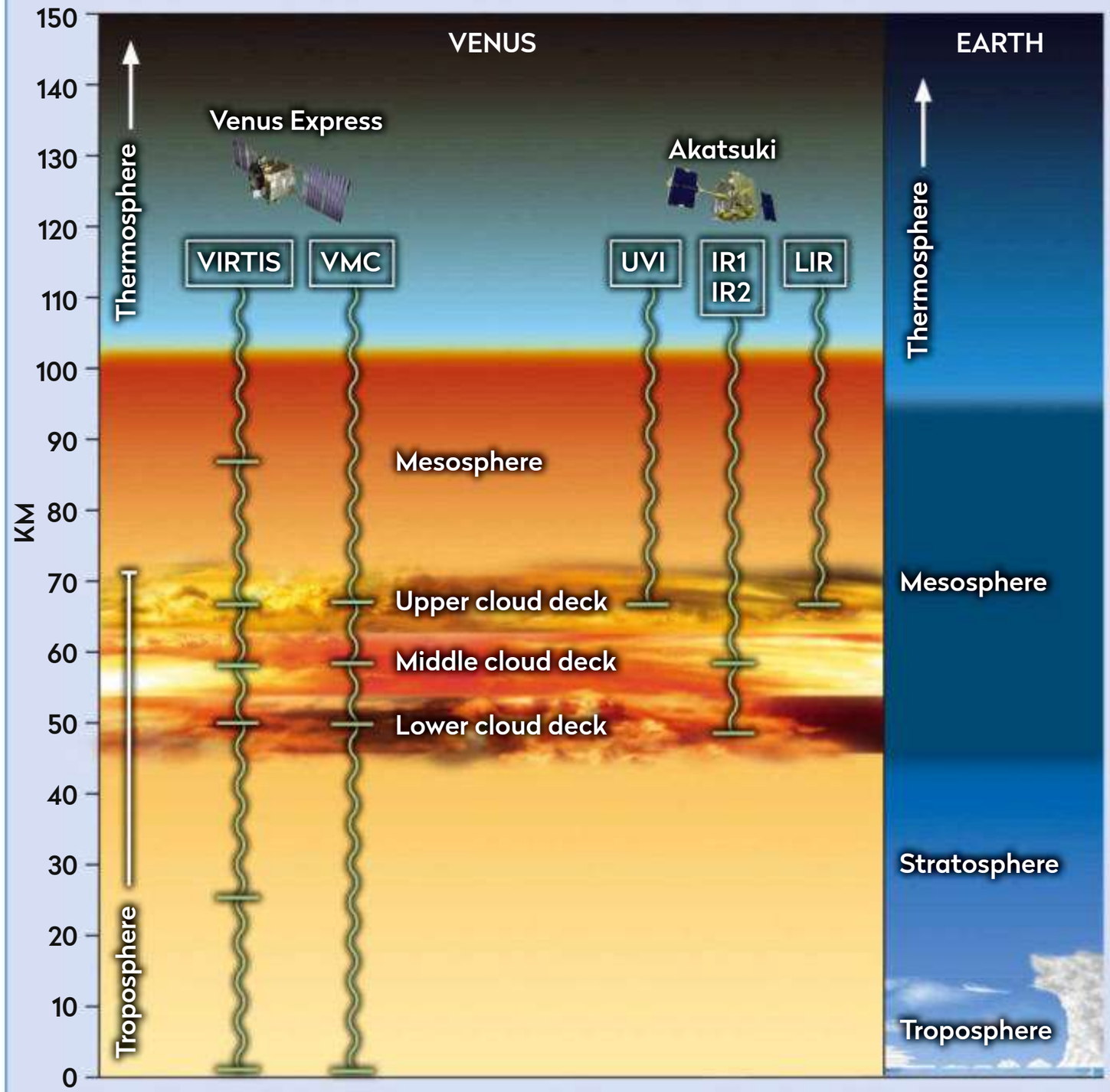
Back on Earth, scientists are still publishing new results from ESA's Venus Express mission, which ended in January 2015, and are studying our neighbour with ground telescopes. In 2020, astronomers announced they'd detected phosphine in Venus's atmosphere using the ALMA observatory. This could be a sign of life in the clouds, or could have spewed from volcanoes. Researchers at Portugal's Instituto de Astrofísica e Ciências do Espaço (IA) recently published a new General Circulation Model for Venus, a computer model of the atmosphere that's the necessary foundation for all predictions of weather and climate. The work focuses on a largely unexplored region of the atmosphere: a layer between the cloudy troposphere and the Sun-heated thermosphere. It explains some previously mysterious data from Venus Express, but more importantly, it generates new, detailed predictions for EnVision to test with observations.

We're getting better at predicting the motions of Venus's winds and clouds, but there's a lot we don't understand. What drives its winds? What's happening below the clouds? Are there active volcanoes today? Why is its atmosphere so thick and choked with carbon dioxide? Did Venus once have liquid water and temperate surface conditions? And what can Venus's conditions today tell us about the future for Earth?

Emily Lakdawalla is a planetary scientist, writer and science communicator

Peering beneath the clouds

How Venus's atmosphere compares to Earth's



Venus's atmosphere is much taller than Earth's, and various exploratory spacecraft that have visited the planet have used scientific instruments to peer through the atmosphere to different depths, giving us detailed information about Venus's sky and thick cloud decks. However, we have much yet to learn. What might future missions reveal about the ground underneath?

JWST will enable scientists to see the stars that formed soon after the Big Bang and to search for traces of oxygen around exoplanets

ILLUSTRATION

READY FOR LAUNCH

The promise of JWST

On the eve of its long-awaited launch, **Govert Schilling** reports on astronomers' expectations for the James Webb Space Telescope

Finally, it's about to happen. All being well, on 18 December, the 6.5-tonne James Webb Space Telescope (JWST) will leave Earth, ready to study the Universe in unprecedented detail. After being launched on a European Ariane 5 rocket, astronomy's new eye on the sky promises to yield new insights into the origin and evolution of planets, stars, galaxies and the Universe as a whole. "JWST has no competition," says long-time project scientist John Mather at NASA's Goddard Space Flight Center. "There is no other way to see what it can see."

Sporting a segmented primary mirror 6.5m in diameter and equipped with sensitive cameras and spectrographs, the James Webb Space Telescope has often been called the successor of the famous Hubble Space Telescope (HST). Indeed, with a light-collecting area almost seven times that of Hubble, JWST is much more sensitive, enabling astronomers to peer further into space and time, and to discern much finer detail in star clusters, stellar nurseries, and galaxies alike.

One important thing that JWST has in common with Hubble is the international character of the project. NASA led the construction of the telescope; the European Space Agency (ESA) provided part of the ▸

NASA GSFC/CIL/ADRIANA MANRIQUE GUTIERREZ

▸ instrumentation and takes care of the launch, and Canada is a third partner. Also, just like Hubble, the JWST is a truly multi-purpose instrument that will leave its mark on almost every field of astronomy. "The science that emerged from the Hubble Space Telescope vastly outdid what we expected," says cosmologist Richard Ellis of University College London. "I'm confident that JWST will do the same."

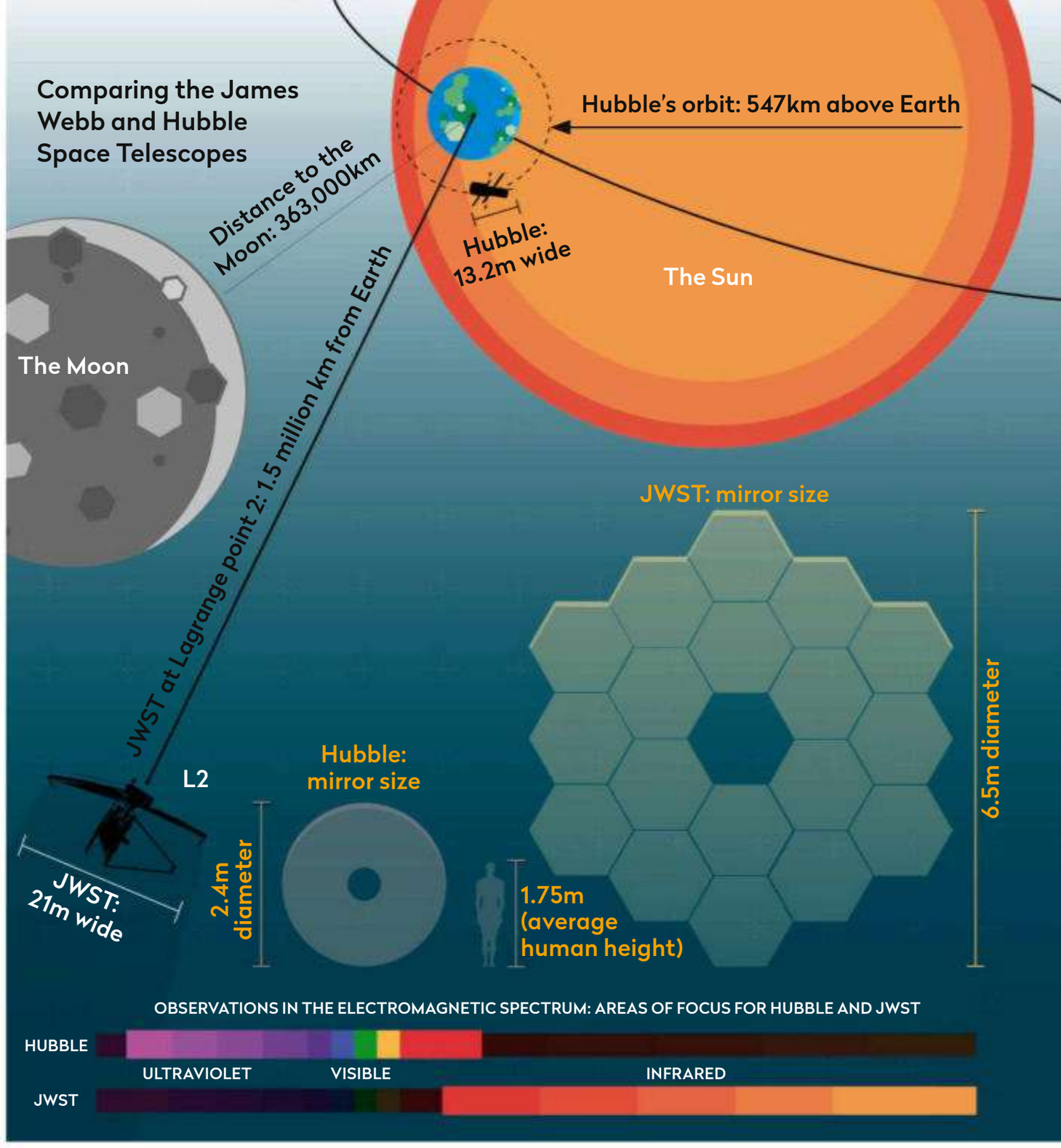
Seeing infrared

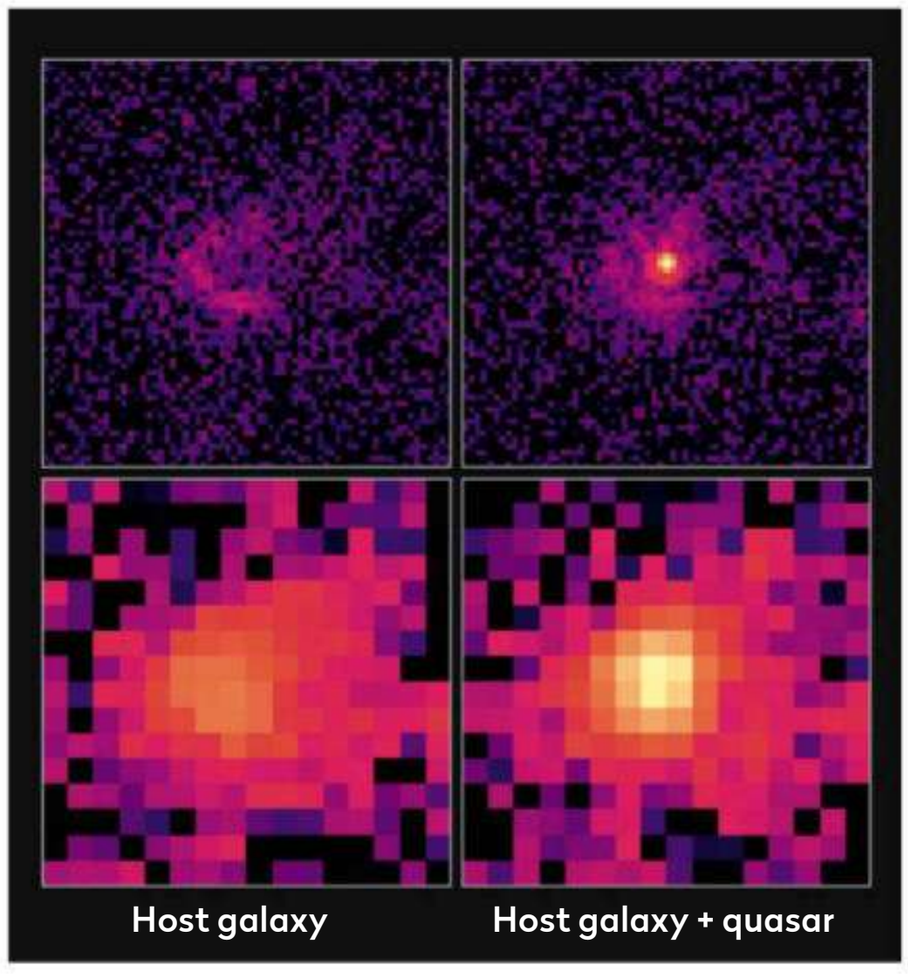
The most important difference between Hubble and JWST (apart from the primary mirror diameter) is that the new space telescope is designed to observe a different set of wavelengths in the electromagnetic spectrum. While Hubble gained fame for its revolutionary discoveries at every colour of the spectroscopic rainbow (plus ultraviolet (UV) and near-infrared), JWST can't see UV, violet, indigo, blue, green or yellow. Instead, it is sensitive to everything between orange light and the mid-infrared, corresponding to wavelengths between 600 nanometres and 28.3 micrometres.

There's good reason for that. Stars are born in the dark and relatively cold interiors of dust-laden clouds of molecular gas that are completely opaque at optical wavelengths. In the (mid-)infrared, however, astronomers can peer through the absorbing dust to witness the birth of new suns and planetary systems. And compared to earlier infrared observatories like NASA's Spitzer Space Telescope, JWST is about a hundred times more sensitive and can also distinguish much finer detail in stellar spectra.

Moreover, as astrochemist Ewine van Dishoeck (from Leiden Observatory in The Netherlands) explains, most complex molecules in the Universe leave their tell-tale 'fingerprints' in the infrared part of the spectrum. "I'm involved in a dozen JWST projects," she says, "and I look forward to measuring the chemical make-up of the material – gases, ices, and silicates – from which planets are built, and to compare that to the composition of the atmospheres of extrasolar planets. JWST will provide an enormous step forward."

According to van Dishoeck, the JWST will also study protoplanetary discs in exquisite detail. "ALMA [the Atacama Large Millimeter-submillimeter Array in Chile] can study the outer parts of these discs," she says, "but JWST will observe the inner parts, where most of the planets are born." Meanwhile, exoplanet researchers like Sara Seager, from the Massachusetts Institute of Technology, hope that the JWST's infrared instruments will be sensitive enough to detect oxygen and other so-called biomarkers in the atmospheres of planets orbiting neighbouring stars. "The most exciting discovery by JWST would be biosignatures in a rocky exoplanet atmosphere, but we have to get lucky," she says.





▲ In addition to its larger mirror and greater distance from Earth, JWST will be concentrating its observations on a different part of the spectrum to Hubble: the infrared

◂ JWST's mirror provides over four times the resolution of Hubble, as these simulated infrared images of a quasar and its host galaxy – taken by JWST (top) and Hubble (bottom) – reveal

Cosmic dawn

Another key science goal of the new space telescope is to search for light from the first stars that formed after the Big Bang – 'witnessing cosmic dawn', as it has been described – and to study the formation and evolution of galaxies. Here, too, infrared astronomy is key. The reason is that light from the earliest phases in cosmic history has been strongly redshifted by the expansion of the Universe by the time it arrives at Earth. In other words: what is emitted in the ultraviolet (the fierce radiation of the very first generation of massive stars) can only be observed in

NASA/J. OLMSTED (STSCI), M. MARSHALL (UNIVERSITY OF MELBOURNE), STOCKTREK IMAGES, INC/ ALAMY STOCK PHOTO, NASA/CHRIS GUNN

JWST will look at the inner parts of protoplanetary discs where planets are born

ILLUSTRATION

"The study of the giant planets will greatly benefit from JWST's unsurpassed infrared capabilities"

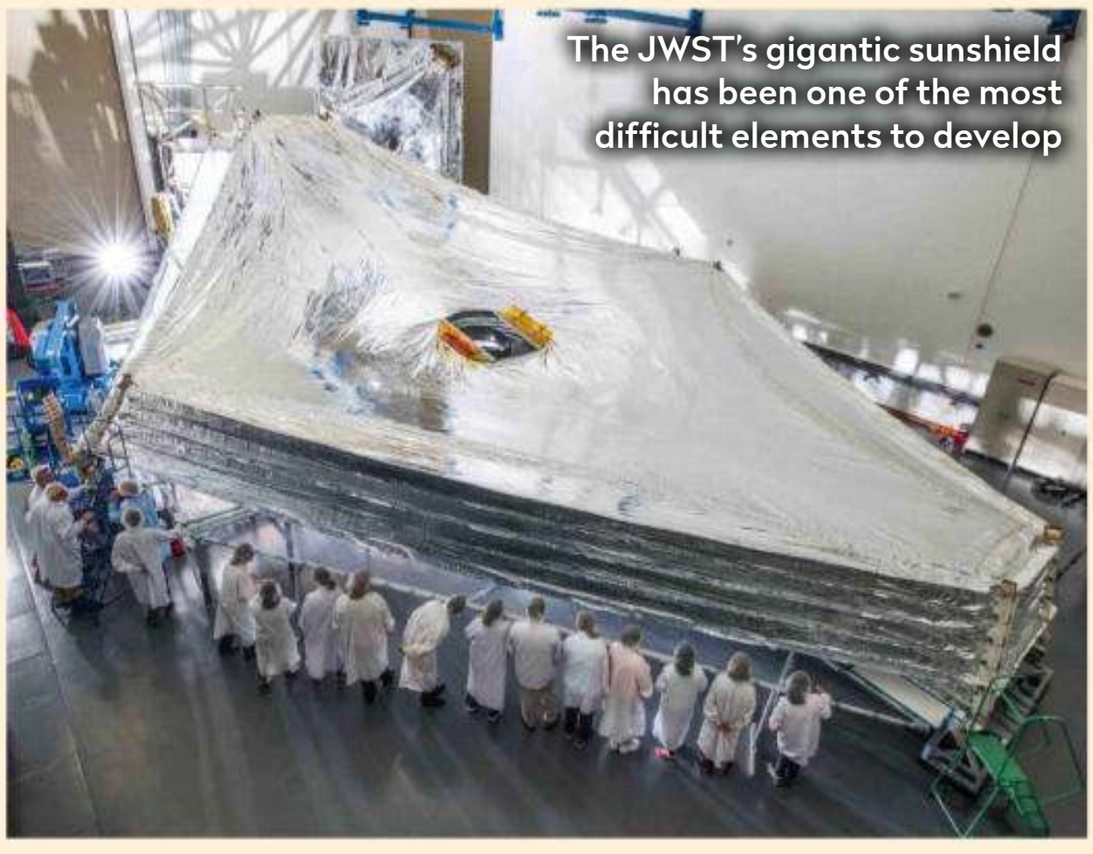
the infrared. "The redshift range [probed by JWST] very much represents the last missing piece in the jigsaw of cosmic evolution," says Ellis.

According to the most recent estimates, the first galaxies emerged some 250 to 350 million years after the Big Bang, and Hubble can't see them because its instruments cannot probe beyond a wavelength of 1.6 micrometres. "My group did well in securing JWST time," says Ellis. "We hope to get spectra of promising examples. Also, tracking the composition of the gas as a function of look-back time is one of our goals."

Closer to home, JWST has much to offer the investigation of our own Solar System. In particular, the study of the giant planets will greatly benefit from JWST's unsurpassed infrared capabilities. At infrared wavelengths, JWST can look below the clouds to see what is happening. "This tells us about the weather and winds, as well as the temperature and chemistry of the atmosphere, which are all really important for learning how these planets work," explains planetary scientist Naomi Rowe-Gurney from the University of Leicester. ▸

Building the most expensive telescope ever

What does it take to construct a telescope like JWST, and why have there been delays?



The JWST's gigantic sunshield has been one of the most difficult elements to develop

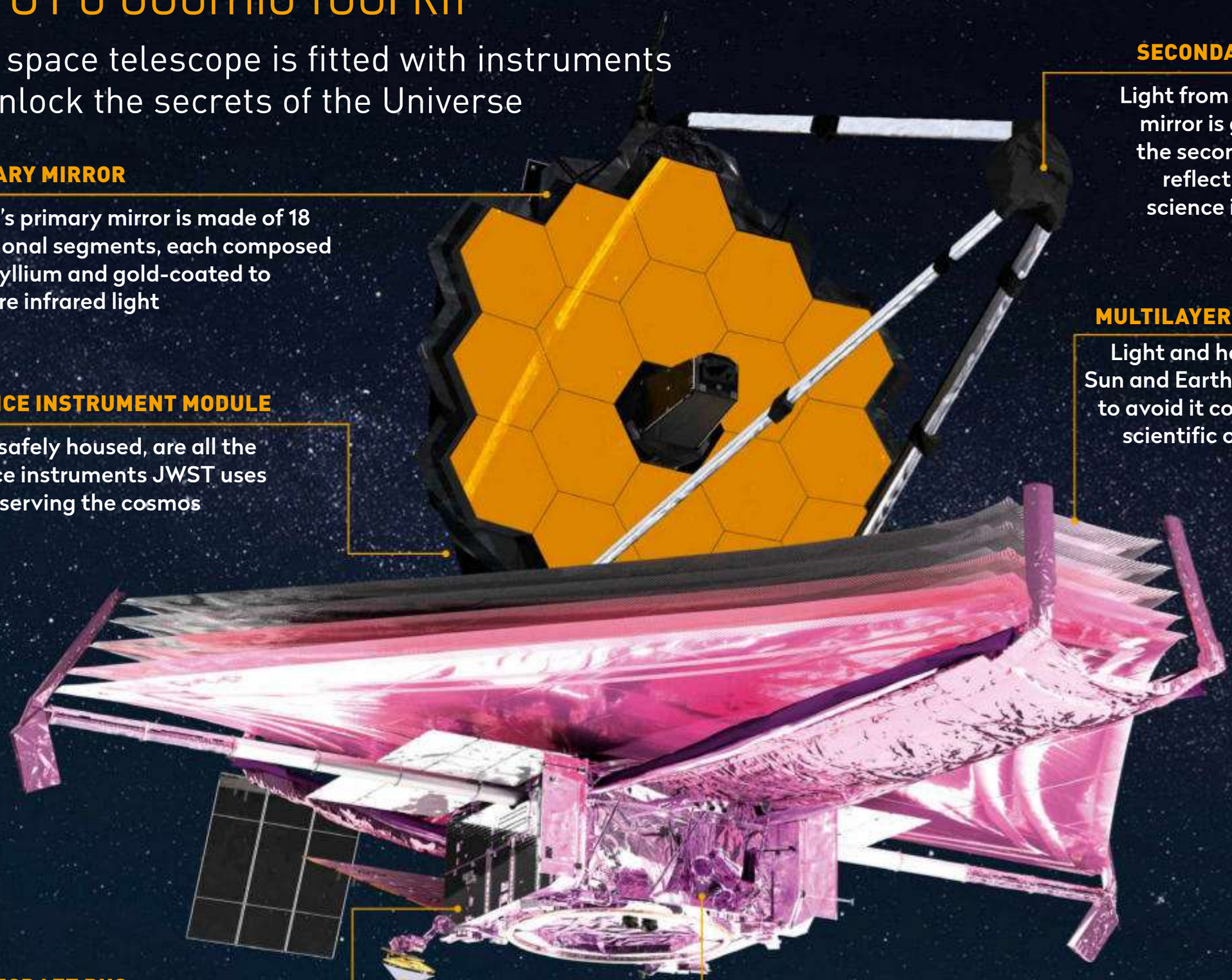
When work on an infrared successor to the Hubble Space Telescope began in 1996, a quarter of a century ago, the plan was to build an 8m instrument that would launch in 2007 and would have a price tag of just $500m. "We were over-optimistic about schedule and budget," says project scientist John Mather of NASA's Goddard Space Flight Center, which manages the development of JWST.

By 2005, cost estimates had risen to a few billion dollars, and NASA called for a redesign with a smaller primary mirror. Still, thanks to many technical setbacks and associated delays – in particular with the development of the vulnerable sunshield – prime contractor Northrop Grumman eventually delivered the telescope in 2016, after which a long period of testing began.

In early 2020, the COVID-19 pandemic caused more delays: NASA had to give priority to completing its Perseverance Mars rover in time for its planned July launch. Eventually, in late August 2021, the JWST was ready for shipment to the European launch base in French Guiana. By then, the project's total costs were just short of $10bn.

JWST's cosmic tool kit

The space telescope is fitted with instruments to unlock the secrets of the Universe



PRIMARY MIRROR

JWST's primary mirror is made of 18 hexagonal segments, each composed of beryllium and gold-coated to capture infrared light

SECONDARY MIRROR

Light from the primary mirror is gathered by the secondary, which reflects it onto the science instruments

MULTILAYER SUNSHIELD

Light and heat from the Sun and Earth is deflected to avoid it compromising scientific observations

SCIENCE INSTRUMENT MODULE

Here, safely housed, are all the science instruments JWST uses for observing the cosmos

SPACECRAFT BUS

Steering and control machinery is stowed away to enable astronomers to manoeuvre the telescope, if need be

HIGH GAIN ANTENNA

Commands from NASA scientists are received by JWST, and its science data is sent back to Earth

STAR TRACKERS

Background stars are tracked and used as guides so JWST can locate its intended target of study

ILLUSTRATION NASA GSFC/CIL/ADRIANA MANRIQUE GUTIERREZ, NASA/CHRIS GUNN X 4

▸ Rowe-Gurney is involved in the first JWST observations of Uranus and Neptune that are scheduled for some time in 2022. "Because we haven't visited either planet since the Voyager 2 flybys in the late 1980s, we have a lot of unanswered questions," she says. "Any questions we can answer with JWST will ultimately help motivate a future dedicated mission to one or both of these ice giants. So look out for some amazing images and ground-breaking science from my two favourite planets!"

In addition, JWST will be a great instrument to study the composition and characteristics of minor Solar System bodies like asteroids, comets and ice dwarfs in the Kuiper Belt, beyond Neptune's orbit.

Fulfilling all these goals is the task of a suite of four big, complicated scientific instruments. Astronomers expect jaw-dropping photographs from the US-built Near-InfraRed Camera (NIRCam), JWST's most important camera, which operates at wavelengths between 0.6 micrometres and 5 micrometres. Detailed spectra in the same wavelength range will be obtained by the European Near-InfraRed Spectrograph (NIRSpec). Europe also built part of the Mid-InfraRed Instrument (MIRI)

"JWST will be a great instrument to study the composition of minor Solar System bodies"

– a combination of a camera and a spectrograph covering wavelengths longer than 5 micrometres. Finally, the Canadian Space Agency (CSA) contributed an instrument that combines Webb's Fine Guidance Sensor (FGS) – used for pointing and stabilising the space telescope – and the Near InfraRed Imager and Slitless Spectrograph (NIRISS).

Into the cold

To keep the instruments at a temperature of at most 50° above absolute zero (lest their own heat radiation would wreck the observations), JWST is fitted with a huge sunshield, measuring 20m by 14m. It is composed of five extremely thin layers of Kapton

An image showing the sunshield after it had completed its critical testing. The sides of the primary mirror are folded into its launch configuration

▲ Technicians examine the JWST's colossal 6.5m primary mirror

▲ Practising 'snow cleaning' on a test mirror using carbon dioxide 'snow'

▲ Having completed tests, the JWST is packaged up for shipment to its launch site

Govert Schilling is an astronomy writer, science journalist and author of *Ripples in Spacetime*

(a polyimide film developed by DuPont), coated with silicon-doped aluminium. And to keep it away from the infrared emission of our home planet, the JWST will not orbit Earth like Hubble does. Instead, it will essentially orbit the Sun, describing a so-called halo orbit around L2, the second Lagrange point in the Sun-Earth system – where the gravitational forces of the Sun and Earth exactly balance the centrifugal force – which is located 1.5 million kilometres behind Earth, as seen from the Sun.

Unlike the crewed spacecraft that have to dock with the International Space Station (ISS), JWST can basically be launched at any convenient time. At the time of writing, the launch date is 18 December. Within weeks of the launch, while cruising to its remote vantage point, JWST will deploy both its fragile sunshield and its folded primary mirror, which consists of 18 gold-plated hexagonal segments. Project scientist John Mather says this is the most critical part of the mission. "Without them, nothing else works. But our deployment has been tested many times, and we have redundant ways to set off every actuator and turn every motor."

Keeping JWST in orbit around L2 will require the incidental firing of its 16 thrusters. Given the amount of on-board fuel, the operational lifetime of the telescope is likely be limited to around 10 years. So unless engineers find a way to robotically refuel JWST, in principle it is possible that its 'predecessor', the Hubble Space Telescope, outlives it – provided Hubble doesn't experience any major technological issues or breakdowns over the next decade.

Meanwhile, astronomers are already discussing plans for the successor to the James Webb Telescope. Four amazingly powerful observatories are on the drawing board, competing for priority and funding. "In my opinion all are worth building," says Mather. "It's only a question of how and when."

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There has been a surge of interest in stargazing in recent months, as people seek to reconnect with nature. Whether you have a telescope or like to look with just your eyes, the SPA can help make the most of your interest in stars and planets. We've been aiding beginners across the UK since 1953, and we are fantastic value. So why not join us! Visit our website to see what we offer.

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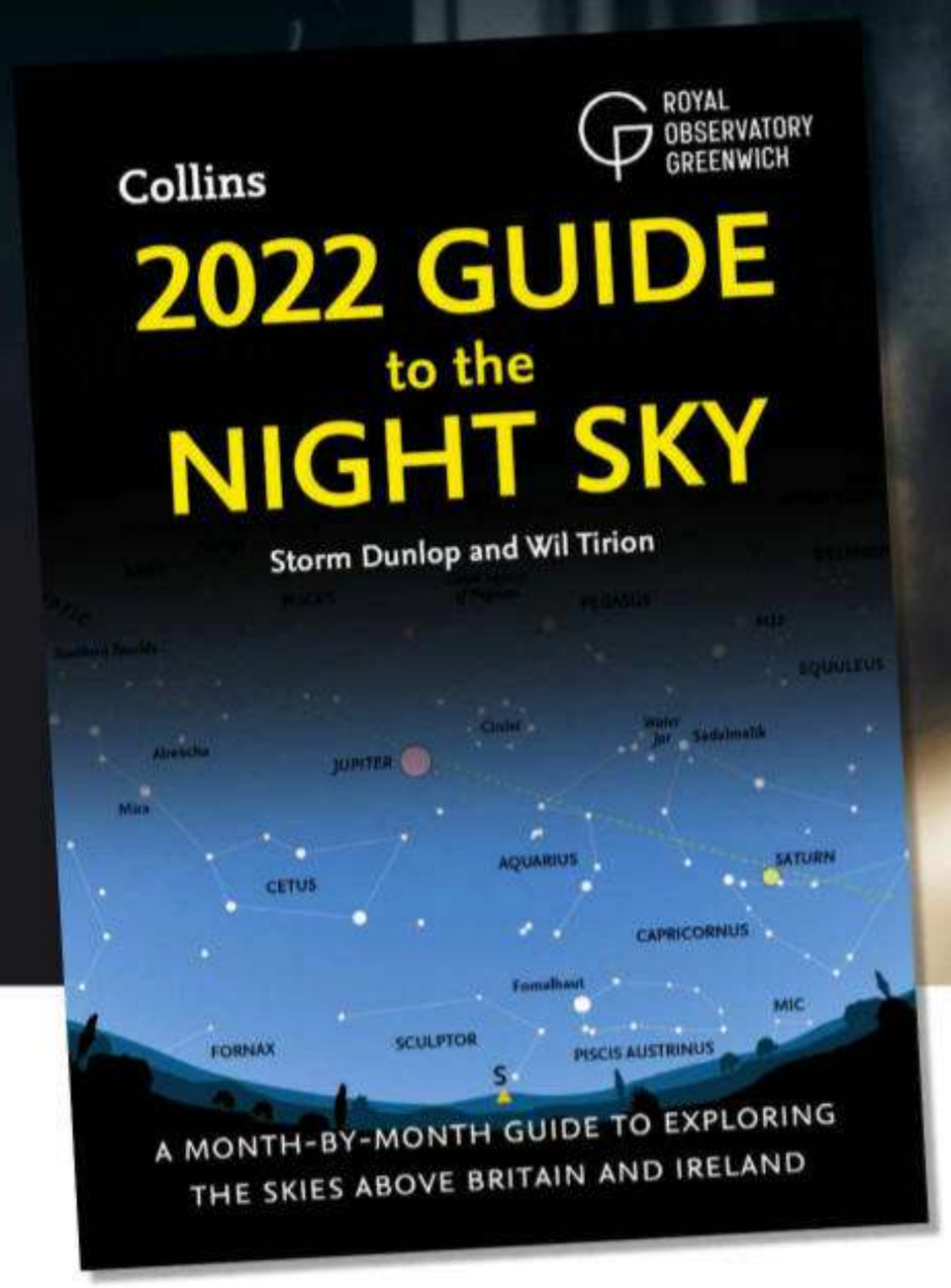

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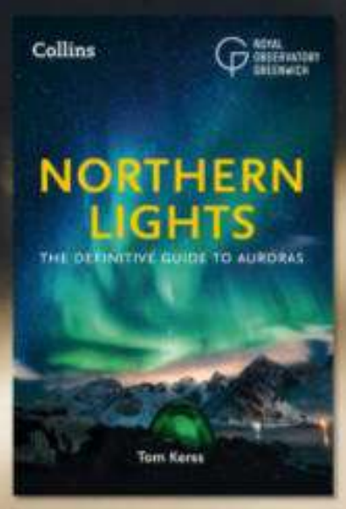

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16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

The Sky Guide

NOVEMBER 2021

PETE LAWRENCE

SHADOW MOON

Watch Earth-shade create a partial lunar eclipse this month

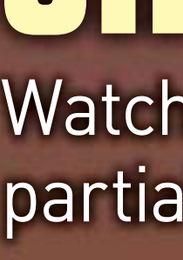
CERES GETS CLOSE

Observe the dwarf planet Ceres reaching opposition in Taurus

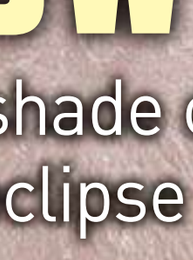
MERCURY MEETS A CRESCENT

Catch morning encounters between the bright inner planet and a waning Moon

About the writers



Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four



Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Shadow transits by Jupiter's moons
- Deep-sky viewing opportunities in Taurus
- Mare Orientale on the edge of the Moon's face

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

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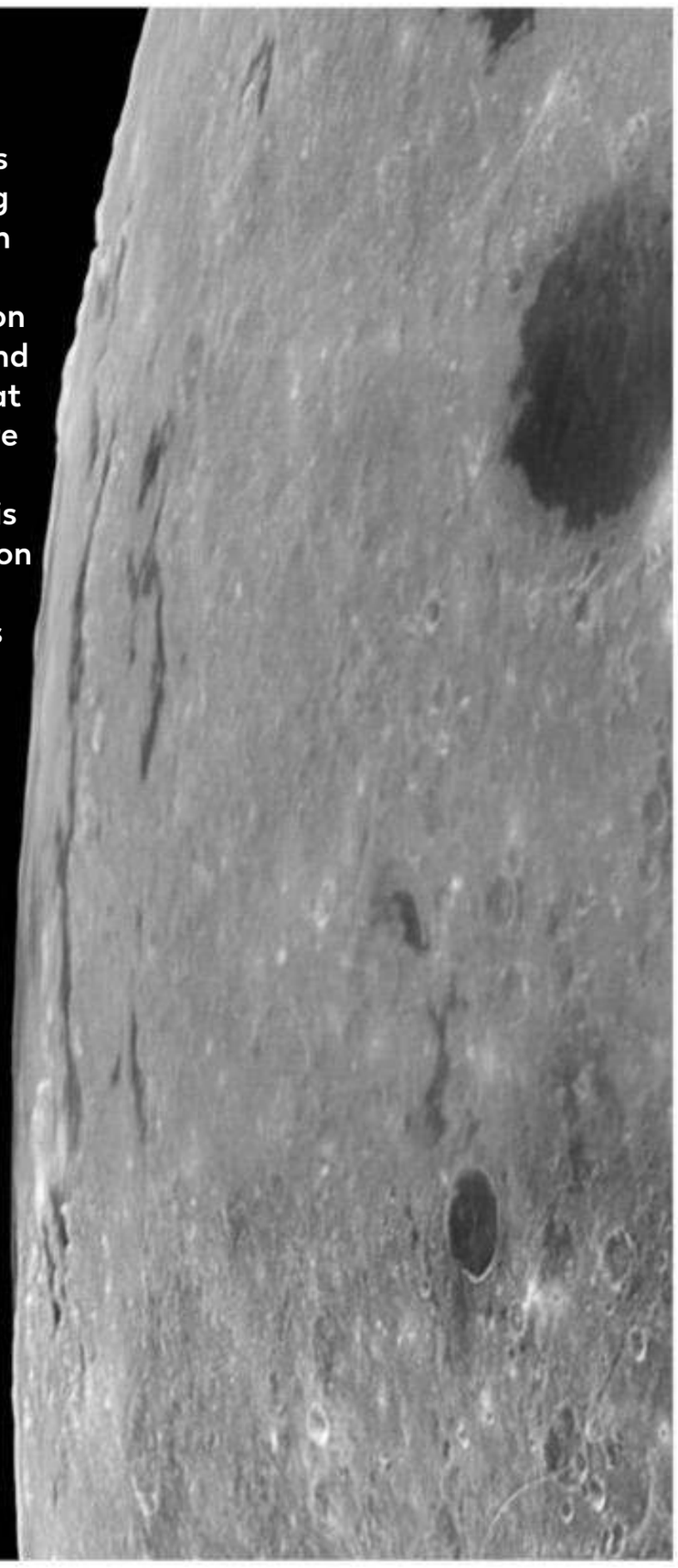
NOVEMBER HIGHLIGHTS

Your guide to the night sky this month

Monday

1 This morning's 17%-lit waning crescent Moon is showing a favourable libration (a small rocking and rolling motion) that will reveal the Mare Orientale region. The 'Eastern Sea' is ironically located on the southwestern limb of the Moon's crescent. See page 47 for more details



Tuesday ▶

2 Early risers will get a view of mag. –0.8 Mercury 4° from mag. +1.0 Spica (Alpha (α) Virginis). Look low above the east-southeast horizon from 06:00 UT. A 9%-lit waning crescent Moon hangs 20° above Mercury.

◀ Friday

5 Uranus reaches opposition on 4/5 October, shining at mag. +5.6 and located in the southern portion of Aries.

Sunday

7 The first of two lovely opportunities to catch a thin waxing crescent Moon with brilliant Venus. Shining at mag. –4.4, Venus lies 7.2° east of this evening's 11%-lit waxing crescent.

Monday

8 Following yesterday evening's meeting of the Moon and Venus, this evening dazzling Venus appears 6.6° west of the 20%-lit waxing lunar crescent.

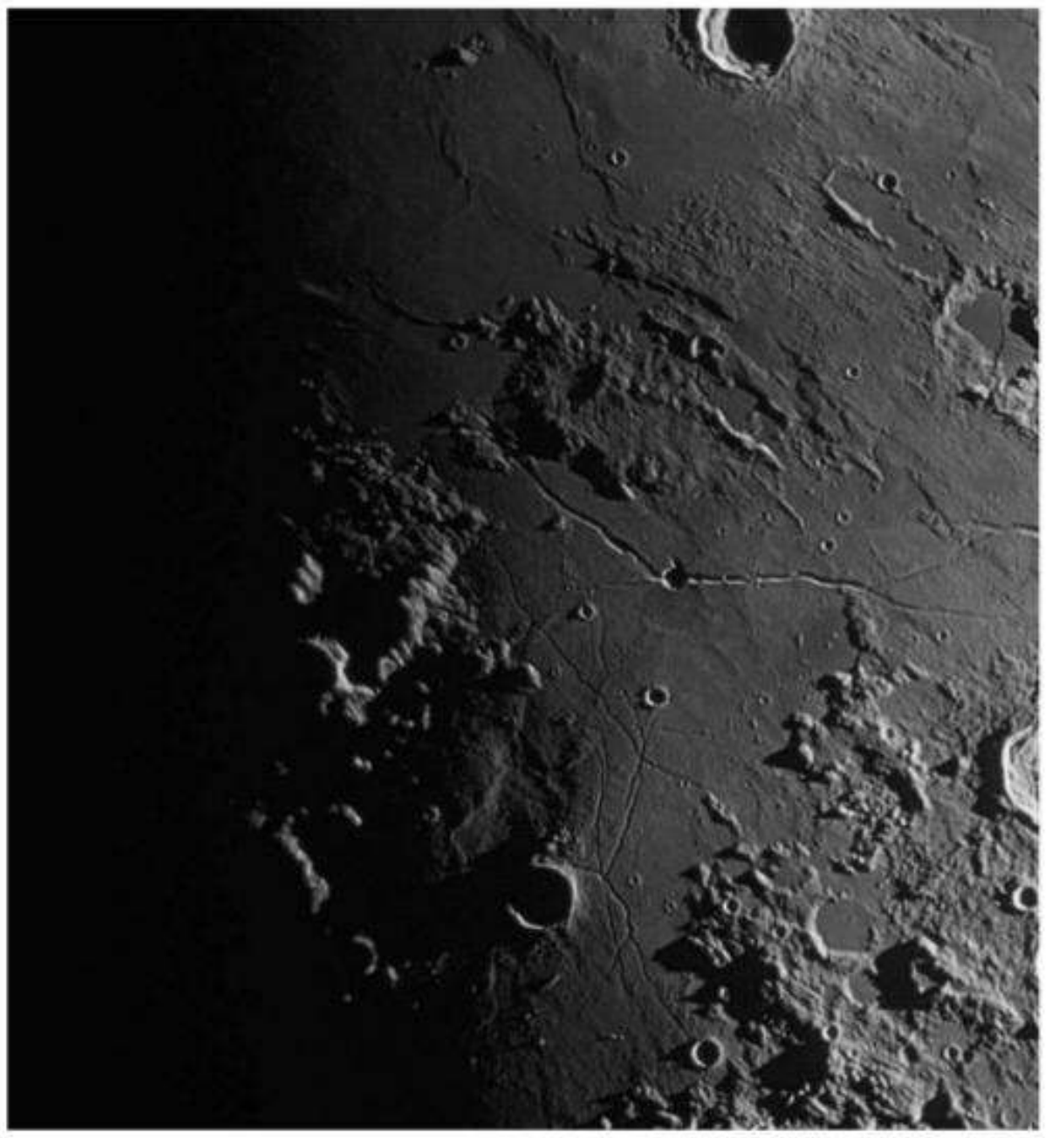
Wednesday

10 This evening's 41%-lit waxing crescent Moon lies 5° south of mag. +0.9 Saturn in an attractive pairing.

Thursday ▶

11 This evening, the first quarter Moon appears 5.2° south of mag. –2.3 Jupiter. See page 47 for details.

The clair-obscur effects known as the 'Lunar X' and 'V' are visible this evening, getting most visible around 22:30 UT. See page 47.



PETE LAWRENCE X 6

Family stargazing

The sky starts to get dark quite early in November. Looking towards the eastern part of the sky early evening, you should be able to spot the small but distinctive open cluster known as the Pleiades. It's roughly a third of the way up the sky when due east, a position achieved at 8:30pm on 1 November, 7:30pm mid-month and 6:30pm at the end of November. An alternative name for the Pleiades is the Seven Sisters, supposedly because that's how many stars are obvious to the naked eye. But is seven the limit? Younger eyes may see more. **www.bbc.co.uk/cbeebies/shows/stargazing**

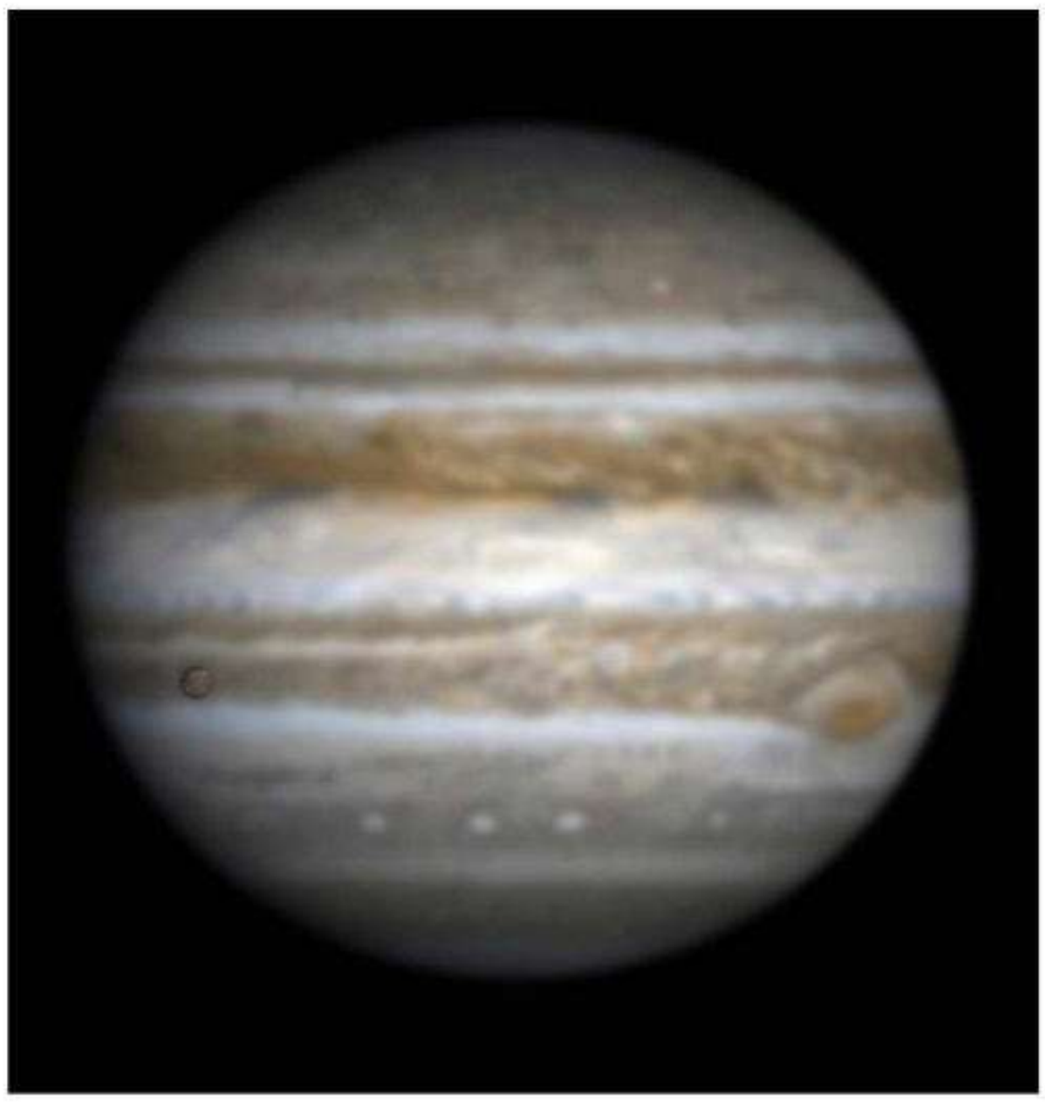
Wednesday ▶

3 A clear sky this morning will bring the stunning sight of mag. –0.8 Mercury and a 3%-lit, waning crescent Moon 6° to the west-northwest (above and slightly right as seen from the UK).

Ceres is 7 arcminutes south of Aldebaran at 00:00 UT.

Thursday

4 Locate mag. –0.8 Mercury in this morning's sky and if the weather is particularly clear, you might be able to see an ultra-thin Moon 7° below and left of the planet as seen from the UK. This Moon, less than 1%-lit, is on the theoretical limit of visibility, the Danjon Limit.



◀ Saturday

6 There's a good opportunity to watch Callisto transit Jupiter's disc this evening. The event begins as the sky starts to darken around 16:45 UT, Callisto eventually leaving transit at 21:20 UT. See page 47 for more details.

Tuesday

9 Catch a view of Jupiter through a telescope as the sky is darkening and you will see the giant shadow of Ganymede in transit across the planet's disc. The event ends at 18:36 UT. Turn to page 47 for more details.

Friday

12 The Northern Taurid meteor shower reaches its peak. The shower has a low ZHR (zenithal hourly rate) of 5 meteors per hour, but this is offset to a degree by a wide, broad peak and slow, bright trails.

Tuesday

16 There's another chance to see Ganymede's shadow transiting Jupiter's atmosphere from 19:08–22:36 UT. See page 47.

At 14:00 UT Ganymede will be transiting Jupiter and covering Io's shadow. Also see page 47.

Wednesday

17 Peak of the annual Leonid meteor shower. Unfortunately, this year's shower will be washed out by a bright Moon, full on the morning of 19 November.

Friday

19 Today's full Moon will be partially eclipsed by Earth's shadow. The event is visible from the UK as the Moon sets. The eclipse's penumbral stage begins at 06:02 UT, and the dark umbral phase starts at 07:18 UT, just a few minutes before moonset.

Saturday

27 Ceres will be at opposition at mag. +7.0 and visible through binoculars.

'The Cutlass' lunar clair-obscur effect is visible tonight. The blade is formed by the Straight Wall, Rupes Recta, and the handle by the Stag's Horn mountains.

Sunday

28 The southwest limb of the Moon is favourably librated towards Earth this morning, giving a reasonable view of the dark lava patches in and around the Mare Orientale basin. Read more on page 47.

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY
If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

DON'T MISS

PARTIAL LUNAR ECLIPSE

BEST TIME TO SEE: 19 November from 06:00 UT until moonset

These illustrations show the Moon's position relative to a flat north-northwest horizon from the centre of the UK at the times shown. This position will vary with location, the eclipse being much better seen towards the north and west of the UK

▲ The partial lunar eclipse takes place as the Moon drops towards the horizon, so make sure you find a location where the view is as clear as possible

To be ready for the partial lunar eclipse on the morning of 19 November, get up nice and early. Around 05:30 UT you'll see a beautiful full Moon shining away above the western horizon. As time goes by and the Moon drops towards the horizon it'll become eclipsed by Earth's shadow, presenting what, it's fair to say, is a tricky partial eclipse.

The background sky will technically still be astronomically dark at this time (the presence of that bright Moon and its reflected sunlight will have an effect of course, but that's not a concern here), but as the Moon appears to drop towards the west-northwest horizon, dawn begins. As the sky lightens, the Moon remains visible – its brightness sustaining the view in the brightening morning twilight.

The Moon enters the weak outer part of Earth's shadow, the penumbra, at 06:02 UT, but this is unlikely to be seen. As time advances, the Moon heads deeper into the penumbra, towards the darker umbral shadow. It reaches the umbral shadow at 07:19 UT and the period leading up to this will show the Moon's northwest limb becoming darker as it enters the denser part of the penumbra. The umbra is more defined and a distinct shadow edge will start to appear after 07:19 UT, but the Moon's low altitude and the brightening sky will make things tricky across the UK.

Eclipse magnitude is a measure of how much of the apparent diameter of the body being eclipsed is covered by the eclipsing entity. In this case the body being eclipsed is the Moon, the eclipsing entity is Earth's shadow. The best views with the greatest magnitude percentages will be from locations further north and west within the UK. If we start with London, the umbra crossing starts just 6 minutes before moonset and the eclipse only reaches a maximum magnitude of 3 per cent before the Moon is lost below the horizon. In contrast, Stornoway on the Isle of Lewis experiences just over an hour of umbral shadow crossing, the partial reaching a peak magnitude of 74 per cent before moonset. From the west coast of Ireland the umbral eclipse begins an hour before moonset, the peak magnitude reaching 68 per cent. The eclipse reaches a magnitude of 18 per cent from the UK's centre, where the Moon sets 20 minutes after the start of the umbral phase.

In order to see anything of this event, it's essential to find a location where the horizon is clear, unobstructed and preferably flat in a west-northwest direction. A seaward horizon in this direction is perfect.

As the Moon moves deeper into Earth's penumbral shadow, its northwest edge will start to darken

ALL PICTURES: PETE LAWRENCE

The Moon's busy crescent phases

BEST TIME TO SEE: As specified

On 1 November, the 17%-lit waning crescent Moon shows favourable libration (a small apparent rocking and rolling motion) for a foreshortened view of the giant concentric region surrounding Mare Orientale on the Moon's southwest limb. There's another similar opportunity around 28 November too, at a greater phase and higher altitude.

In the ensuing days the thinning waning crescent Moon presents some interesting opportunities. On 2 November, the 9%-lit waning crescent appears in the early morning sky along with mag. –0.8 Mercury. The bright inner planet will be located 4° from mag. +1.0 Spica (Alpha (α) Virginis).

A day later, on the morning of 3 November, the now 3%-lit lunar crescent lies 6° to the west-northwest (above and slightly right from the UK) of mag. –0.8 Mercury. This is a good opportunity to spot and identify this tricky planet if you've never seen it before.

▲ There's an opportunity to see the heavily foreshortened features surrounding Mare Orientale on the mornings of 1 and 28 November

Amazingly, if the sky is clear on the morning of 4 November the now ultra-thin lunar crescent may still be seen 7° below and to the left of Mercury as seen from the UK. This waning crescent will be less than 1%-lit and right on the theoretical threshold of visibility – so don't expect this to be easy!

The evening reappearance of the Moon places it near to brilliant Venus on the evenings of 7 and 8 November. On the 7th, the 11%-lit waxing crescent Moon sits 7.2° to the west of mag. –4.4 Venus. Then, on 8 November the Moon, now 20%-lit, appears 6.6° to the east of Venus.

On the evening of 11 November, the first quarter Moon near to Jupiter (see below) will be exhibiting the clair-obscur effects known as the 'Lunar X' and 'Lunar V'. Both lighting effects reach a peak around 23:30 UT, when the letters X and V will be visible on the lunar terminator with a telescope.

Jupiter moon events

BEST TIME TO SEE: As specified

As Jupiter drifts closer towards the evening twilight, there is still time for a few interesting events regarding its four largest moons. On 6 November there's a great opportunity to see the outer Galilean moon, Callisto, transiting Jupiter's disc. The event conveniently begins as darkness falls at around 16:45 UT, Callisto moving off Jupiter's disc at 21:20 UT. Transits of Callisto only occur when viewing relatively close to a Jovian equinox, as occurred in May of this year.

On 9 November, there's another conveniently timed event visible as the sky is darkening. A telescope will show the large dark shadow of Ganymede as it crosses the atmosphere of Jupiter.

This event plays out until 18:36 UT. However, if you miss this transit, there's another opportunity to see Ganymede's huge shadow in transit on 16 November. This particular event starts under dark-sky conditions, beginning at 19:08 UT and concluding at 22:36 UT.

For those without the aid of a telescope, there's a wonderful meeting between the first quarter Moon and mag. –2.3 Jupiter on the evening of 11 November. At 21:45 UT, as the pair approach the southwest horizon prior to setting, they will be around 5° apart – that's about 10 apparent Moon diameters.

A south-up view of Callisto in transit over Jupiter's disc on 6 November at 19:00 UT

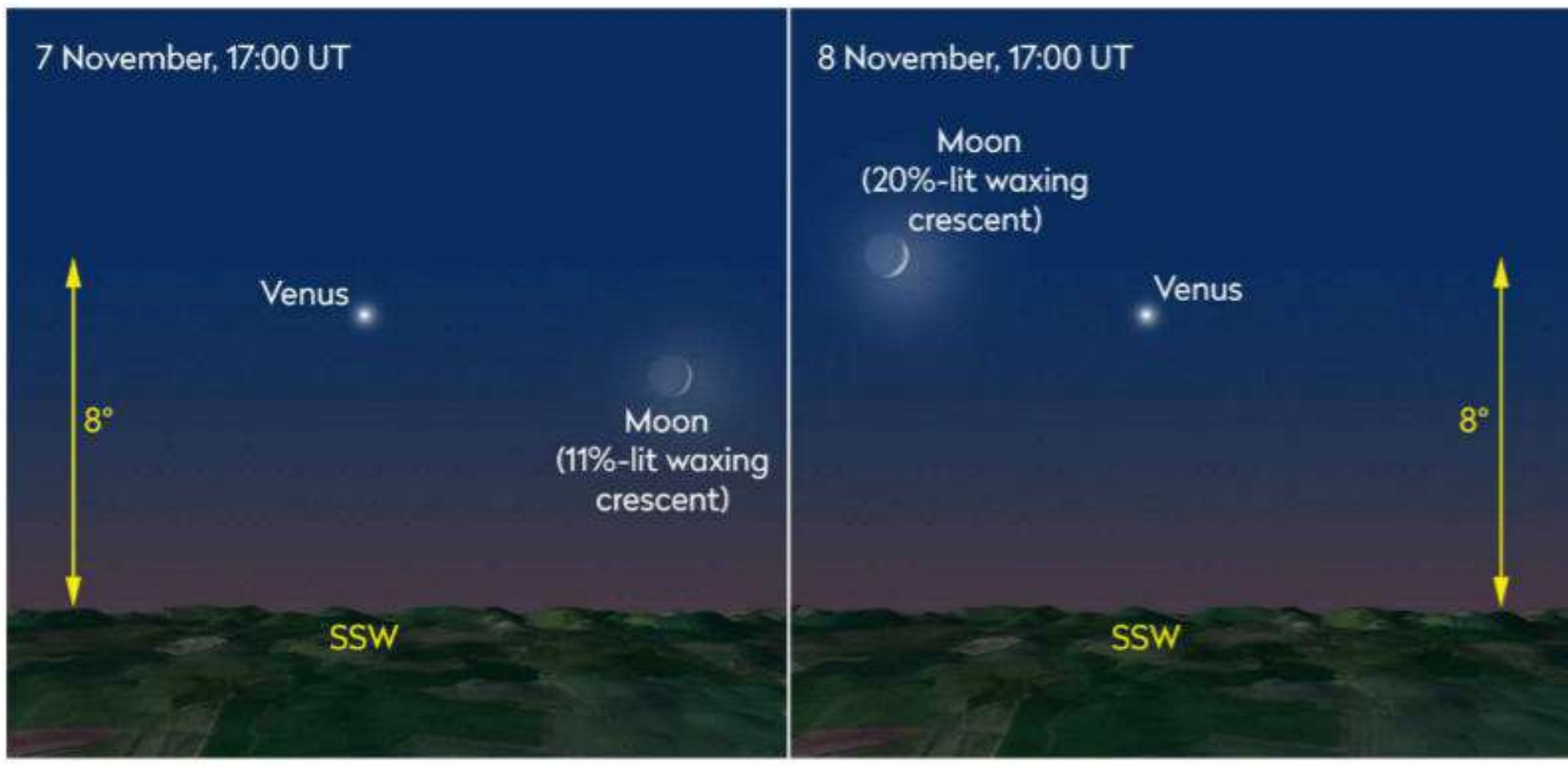
THE PLANETS

Our celestial neighbourhood in November

PICK OF THE MONTH

Venus

Best time to see: 30 November, from 16:30 UT
Altitude: 10°
Location: Sagittarius
Direction: South-southwest
Features: Phase, subtle atmospheric shadings
Recommended equipment: 75mm or larger



▲ **View a crescent Moon to the west of Venus on 7 November and to its east on the 8th**

Venus is an evening object, suffering from being in a southern ecliptic part of the sky. In fact, it's currently in Sagittarius, the most southerly of the Zodiacal constellations, and this keeps its altitude low as seen from the UK. Despite this, at mag. –4.7 Venus is intensely bright and as long as your south through to west-southwest horizon is relatively clear you should be able to see it, weather-permitting of course.

Venus reached greatest eastern elongation on 29 October when it appeared separated from the Sun by 47°. It's now heading back towards the Sun, gathering pace as it speeds towards inferior conjunction on 8 January. It sets 100 minutes after the Sun on 1 November, a figure which increases to 150 minutes by the end of the month.

Venus's November passage against the stars takes it through the Teapot asterism in Sagittarius, the planet passing across the northern regions of the Teapot's handle in the middle of the month. An 11%-lit waxing crescent Moon lies west of Venus on 7 November, while a 20%-lit waxing crescent lies to the east of the planet on 8 November.

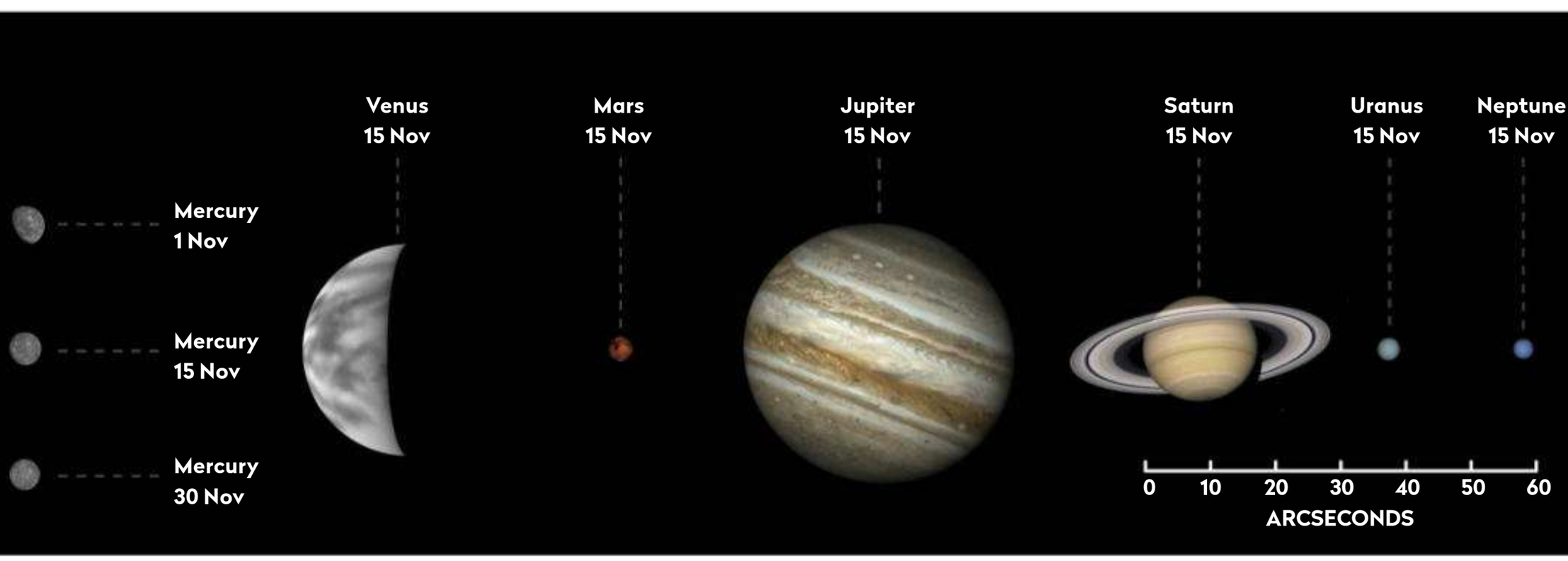
Telescopically, Venus is entering its majestic crescent phase, appearing thinner with each passing day. Unfortunately, a thin crescent and low altitude are not a good combination, and the poor atmospheric conditions experienced when viewing a planet close to the horizon will make it tricky to get a sharp view of Venus's beautiful shape. On 1 November, Venus exhibits a 47%-lit phase, with an apparent diameter of 25 arcseconds. By the end of the month, the phase will have reduced to 28%-lit while the apparent diameter will have increased to 38 arcseconds.

▲ **Through a telescope: Venus enters its crescent phase, appearing thinner each day**

PETE LAWRENCE X 3

The planets in November

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



Mercury

Best time to see: 1 November, from 06:15 UT
Altitude: 6° (low)
Location: Virgo
Direction: East-southeast
Mercury is a well-positioned morning object at the start of November, rising 100 minutes before sunrise. For most of the month it's approaching superior conjunction, which finally occurs on the 29th. Despite losing separation from the Sun, Mercury's brightness increases over the month, from mag. –0.8 on the 1st to –1.2 by the month's end. On the 3rd a 3%-lit waning crescent Moon lies 6° northwest of Mercury. The planet rises 90 minutes before the Sun on this date.

Mars

Best time to see:
30 November, 07:00 UT
Altitude: 4° (low)
Location: Libra
Direction: Southeast
Mars is a morning object, too close to the Sun to be seen properly at the month's start, but getting sufficient separation so that its mag. +1.6 dot can be seen after the first week. On the 10th and 11th, mag. +1.6 Mars sits near to mag. –0.8 Mercury, both planets being about 1° apart on these dates.

Jupiter

Best time to see: 1 November, from 18:00 UT
Altitude: 21°
Location: Capricornus
Direction: South
Jupiter is now easy to observe in the evening sky, reaching its highest position, due south, in the early evening. At this time, it will be 22° up. The first quarter Moon sits 5° south of mag. –2.3 Jupiter on the 11th. By the month's end, Jupiter's southerly position is compromised by evening twilight.

Saturn

Best time to see: 1 November, from 18:00 UT
Altitude: 18°
Location: Capricornus
Direction: South
As we approach the year's end, the placement of the gas giants Jupiter and Saturn becomes compromised by twilight. At the start of November, Saturn can be viewed at its highest point in the sky, due south, in darkness, but by the month's end you'll struggle to see it in this position. As the sky does darken towards the end of the month, look out for Jupiter, Saturn and Venus, all in a line with Saturn in the middle.

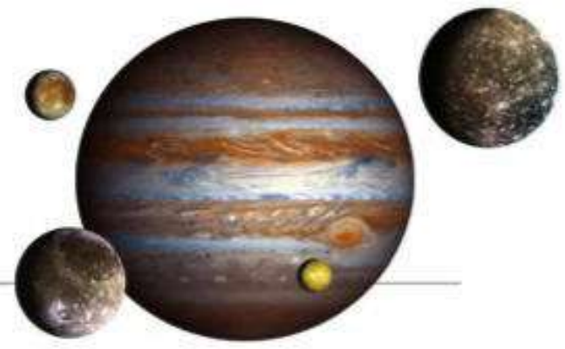
Uranus

Best time to see: 4 November, around midnight
Altitude: 52°
Location: Aries
Direction: South
Uranus reaches opposition on 4 November and is visible all night long. It reaches an altitude of 52° when due south, as seen from the centre of the UK. A bright, almost full Moon sits 1.8° south of mag. +5.7 Uranus on the morning of the 18th around 04:00 UT.

Neptune

Best time to see: 1 November, 21:00 UT
Altitude: 32°
Location: Aquarius
Direction: South
Neptune remains well-positioned all month, an evening planet near mag. +4.2 Phi (φ) Aquarii. The long dark nights allow it to appear at its highest position in the sky, due south under dark-sky conditions. Shining at mag. +7.9, binoculars are required.

More **ONLINE**
Print out observing forms for recording planetary events



JUPITER'S MOONS: NOV

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 00:00 UT.

THE NIGHT SKY – NOVEMBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

Arcturus — STAR NAME

PERSEUS — CONSTELLATION NAME

GALAXY

OPEN CLUSTER

GLOBULAR CLUSTER

PLANETARY NEBULA

DIFFUSE NEBULOSITY

DOUBLE STAR

VARIABLE STAR

THE MOON, SHOWING PHASE

COMET TRACK

ASTEROID TRACK

STAR-HOPPING PATH

METEOR RADIANT

Circlet — ASTERISM

PLANET

QUASAR

STAR BRIGHTNESS:

MAG. 0 & BRIGHTER

MAG. +1

MAG. +2

MAG. +3

MAG. +4 & FAINTER

5° N E W S — COMPASS AND FIELD OF VIEW

MILKY WAY

When to use this chart

1 November at 00:00 UT
15 November at 23:00 UT
30 November at 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in November*

Date	Sunrise	Sunset
1 Nov 2021	07:09 UT	16:37 UT
11 Nov 2021	07:28 UT	16:19 UT
21 Nov 2021	07:47 UT	16:05 UT
01 Dec 2021	08:03 UT	15:55 UT

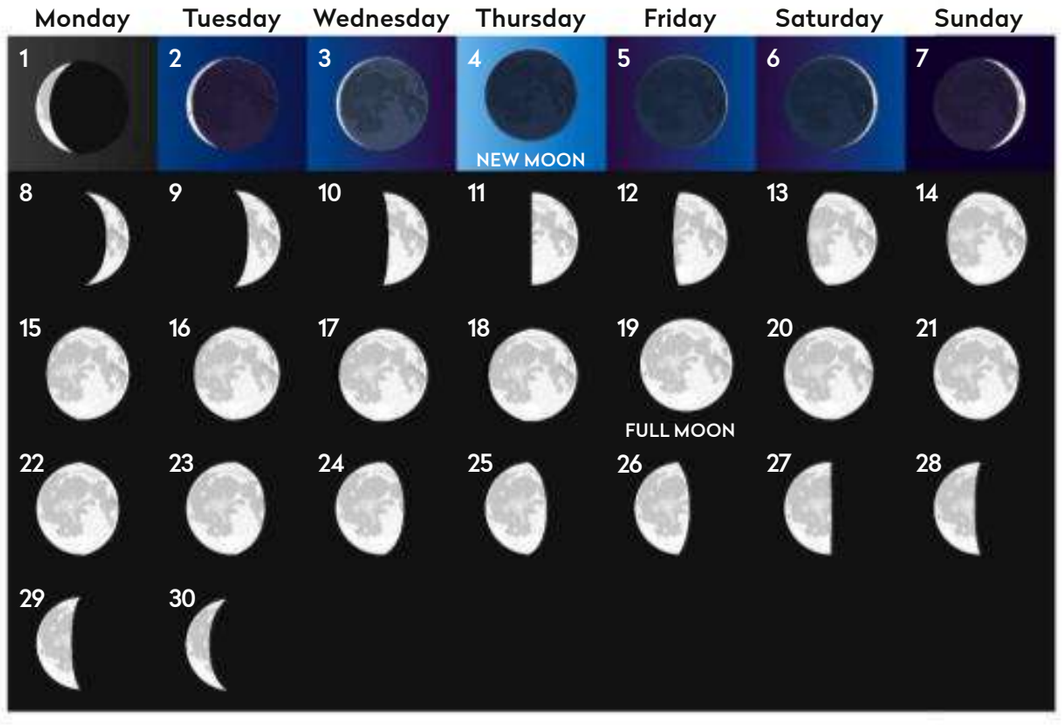
Moonrise in November*

Moonrise times

1 Nov 2021, 01:59 UT	17 Nov 2021, 15:39 UT
5 Nov 2021, 07:55 UT	21 Nov 2021, 17:05 UT
9 Nov 2021, 13:15 UT	25 Nov 2021, 20:59 UT
13 Nov 2021, 14:53 UT	29 Nov 2021, 00:56 UT

*Times correct for the centre of the UK

Lunar phases in November



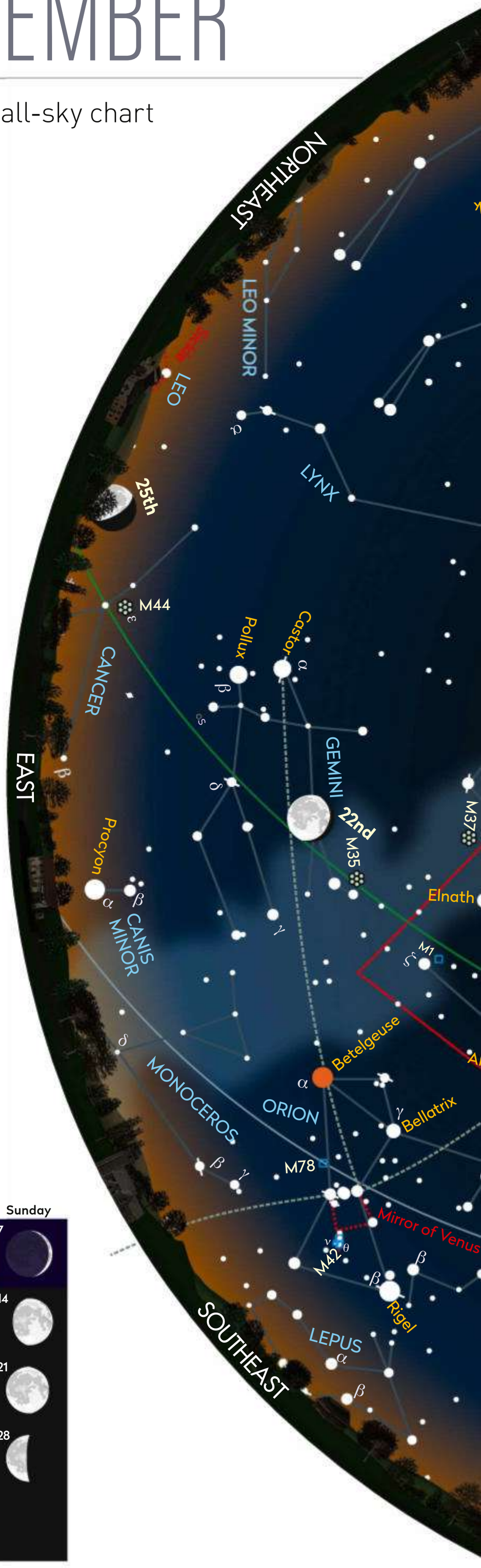


CHART: PETE LAWRENCE

NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
URSA MAJOR
Alcor
Mizar
M101
Thuban
Plough
Dubhe
Merak
Kochab
URSA MINOR
Polaris
DRACO
M92
Vega
LYRA
M57
RR Lyr
AF
Summer Triangle
M56
Albireo
VULPECULA
M27
M71
SAGITTA
Deneb
CYGNUS
Northern Cross
M29
Alderamin
CEPHEUS
House
M39
CAMELOPARDALIS
M52
LACERTA
W
M103
CASSIOPEIA
Schedar
Double Cluster
Mirphak
Capella
AURIGA
Kids
M82
M81
M38
M36
Algol
M34
PERSEUS
M110
M31
M32
Alpheratz
Scheat
PEGASUS
Great Square of Pegasus
M15
EQUULEUS
M2
DELPHINUS
Steering Wheel
TAURUS
ANDROMEDA
M33
TRIANGULUM
Hamal
ARIES
Pleiades
Northern Taurids Peak 12 Nov
Aldebaran
Hyades
19th
Deep-sky tour, p56
Ecliptic
Uranus
16th
PISCES
Circlet
AQUARIUS
Neptune
13th
Celestial Equator
Menkar
Miira
CETUS
Zaurak
ERIDANUS
Deneb Kaitos
FORNAX

MORE **ONLINE**

Paul and Pete's night-sky highlights

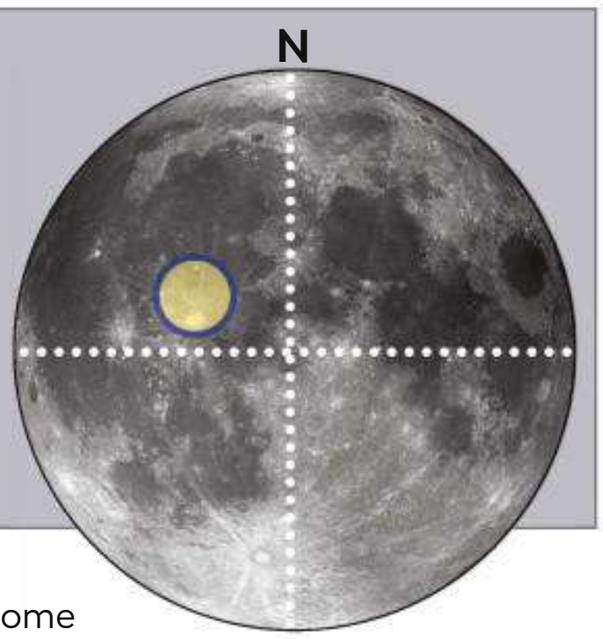
Southern Hemisphere sky guide

MOONWATCH

November's top lunar feature to observe

Montes Carpatus

Type: Mountain range
Size: 300km x 95km
Longitude/Latitude: 23.6° W, 14.7° N
Age: 3.2–3.9 billion years
Best time to see: Two days after first quarter (13–14 November) or one day after last quarter (27–29 November)
Minimum equipment: 50mm refractor



Mare Imbrium (1,250km) is bounded by some impressive mountain ranges. One of them, **Montes Carpatus**, is located along the mare's southern edge, to the north of the impressive 93km ray crater **Copernicus**. Although it lacks the grandeur of the lunar Apenninus, Caucasus and Alpes ranges that define Imbrium's eastern border, there's still plenty of interest to see within the Carpatus mountains.

The range runs for approximately 300km in an east-west line. Its southern flanks have been interrupted by secondary impacts from the formation of **Copernicus**. This is evident in the eastern section of Montes Carpatus, where small chains of craters can be seen radially aligned to the centre of Copernicus. Two distinct craters can also be seen north of Copernicus, invading the range. The larger one is 27km **Gay-Lussac**; the smaller, to the southeast of Gay-Lussac, is 14km **Gay-Lussac A**. Furthermore, immediately north of Gay-Lussac is the irregular shape of 11km x 5km **Gay-Lussac D**. This appears to border a region where lava has infiltrated the Carpatus mountains, creating a division through the range. This 25km-wide expanse of lava runs from Mare Imbrium almost to the northern edge of Gay-Lussac.

Evidence for the inflow of lava into the Carpatus mountains can be found along the northern edge of the range from the mid-section and further west. There appears to be a linearity to some of the features here, oriented towards Mare Imbrium. As you head west you eventually arrive at the 34km crater **T Mayer**, named after Tobias Mayer, an 18th-century German astronomer. T Mayer has a flat floor with two small clusters of peaks, one near the southwest rim, one northeast of the crater's centre. Immediately to the east is the smaller 16km **T Mayer A**. This has well-defined, wide and steep rims which lead down to a flat floor.

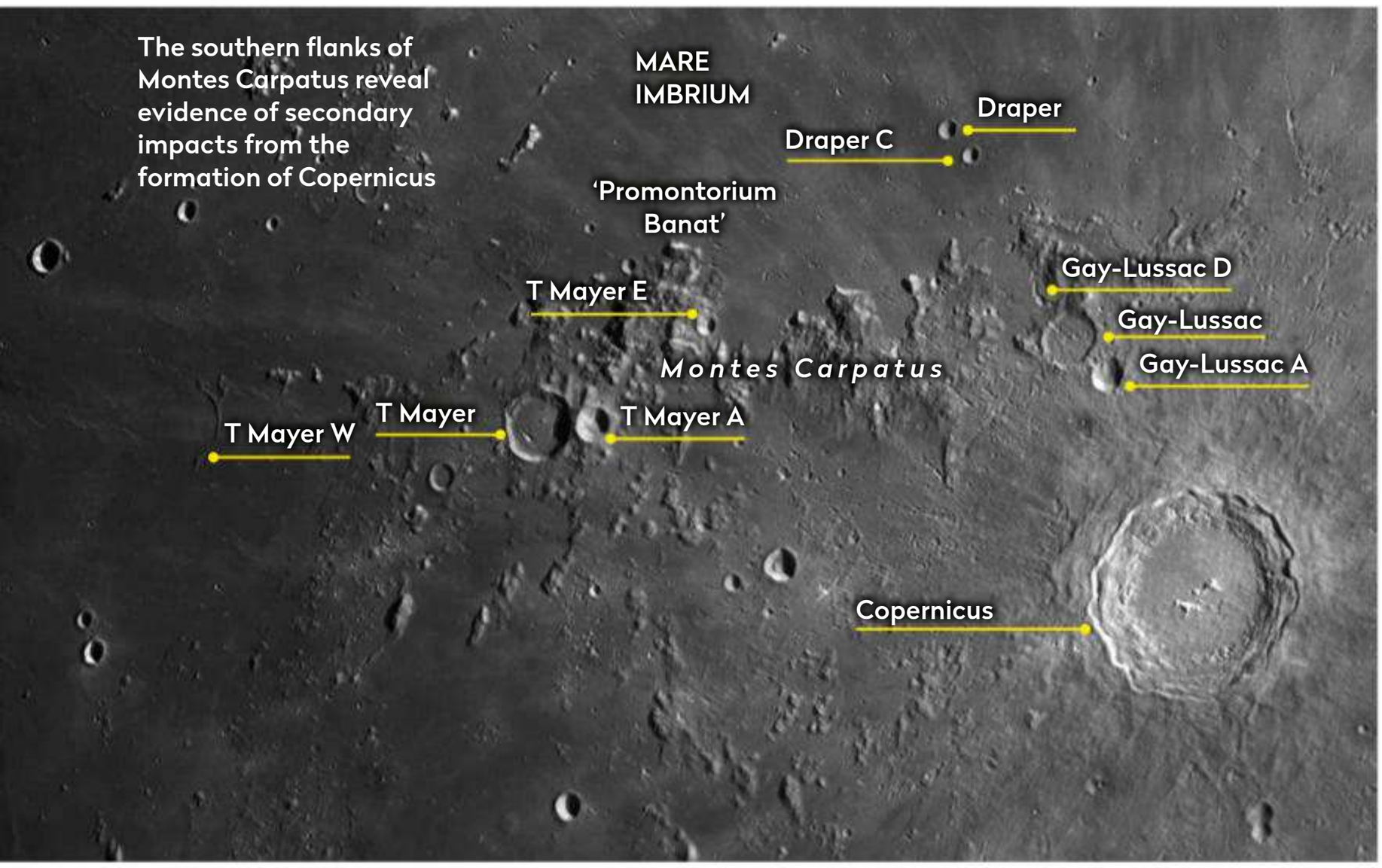
The Montes Carpatus range runs for approximately 300km in an east-west line

Both craters appear towards the western end of the Carpatus range. West of T Mayer lava wins out, covering most of the mountains to leave just a few solitary peaks poking out. It is worth following the range to its conclusion as this leads to one of the more extreme examples of a flooded crater, **T Mayer W**. This sizeable feature could be described as an 'almost' ghost crater. With a diameter of 34km, virtually all of this feature is hidden under the Imbrium lava. However, the rim to the east is elevated enough to poke demonstrably above the mare's surface. With good illumination, it's also possible to see the vague remnant of the rest of the rim. A bright Copernican ejecta ray passes through T Mayer W.

The peaks located to the west and northwest of 9km **T Mayer E** appear bright when the morning terminator passes over them, producing a roughly triangular appearance unofficially known as 'Promontorium Banat'. It is in this region that the highest mountain of the Carpatus range is located, its peak rising to the low altitude of 2.1km. As you move your gaze north from here into the dark lava plain of Mare Imbrium, it's interesting to note the variations in surface brightness. These differences are again mostly caused by the impact ejecta from Copernicus overlaying the darker lava, which fills the mare.

PETE LAWRENCE X 3

▼ The highest mountain of the Montes Carpatus range is located in the 'Promontorium Banat' region

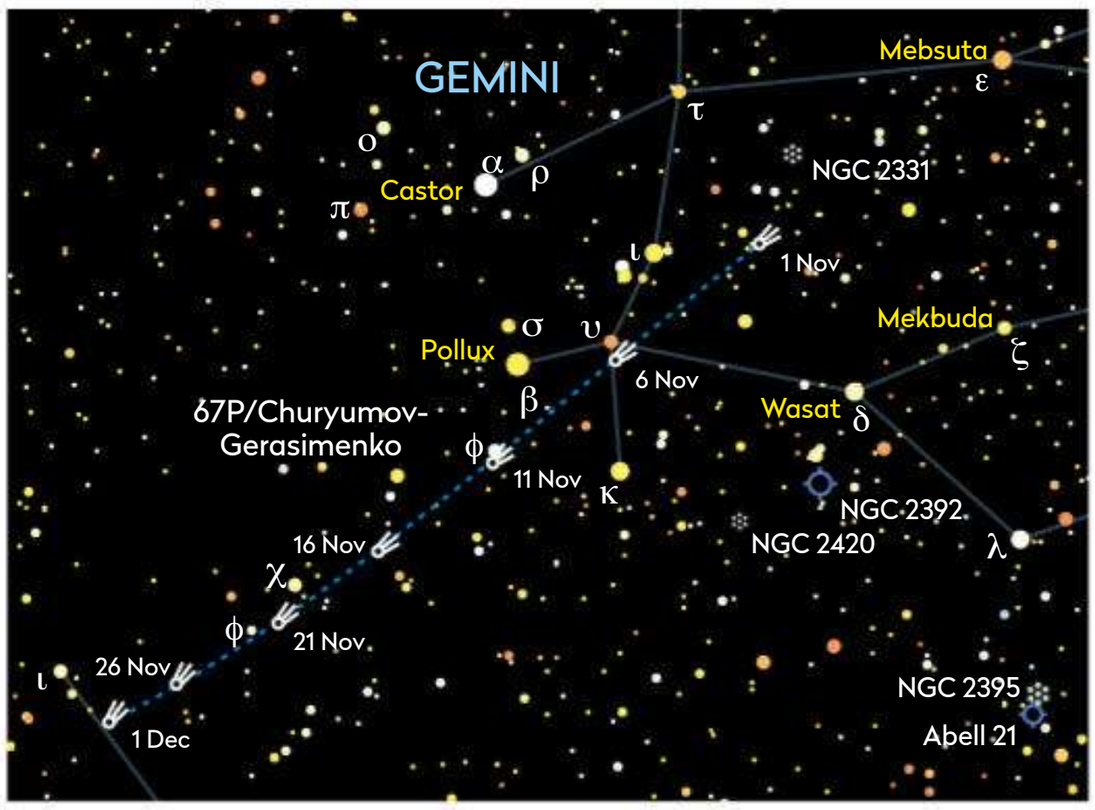


COMETS AND ASTEROIDS

Follow 67P/Churyumov-Gerasimenko as it crosses from Gemini into Cancer

Comet 67P/Churyumov-Gerasimenko is the comet made famous by ESA's spectacular Rosetta mission. This month it can be found passing from Gemini into Cancer. At 00:00 UT on 1 November, 67P is located 2° southwest of mag. +3.8 Iota (ι) Geminorum, and predicted to appear at integrated magnitude +10.7. On the night of 3/4 November it passes approximately one degree south of Iota Geminorum heading east. It lies 40 arcminutes southwest of mag. +4.1 Upsilon (υ) Geminorum at 00:00 UT on 5 November, and southeast of the star by a similar distance at 00:00 UT on the 6th. At 00:00 UT on 8 November it lies 1.6° south of Pollux (Beta (β) Geminorum). The comet then passes close to mag. 5.0 Phi (φ) Geminorum on the nights of 9/10 and 10/11 November, and 30 arcminutes south of mag. +5.1 Chi (χ) Cancri on 18/19 November. 67P can be found 2° south of mag. +4.0 Iota (ι) Cancri during the morning of the 30th. The comet remains at a fairly constant brightness throughout the month and is predicted to dim marginally to mag. +10.9 by its end.

67P/Churyumov-Gerasimenko is a Jupiter-family comet. This is a class of periodic comets with orbital periods less than 20 years, and orbital inclinations of less than 30°. Its orbit takes it



▲ **Comet 67P maintains similar brightness throughout November**

out as far as 5.63 AU from the Sun at aphelion and in as close as 1.243 AU at perihelion. The next perihelion occurs on 2 November.

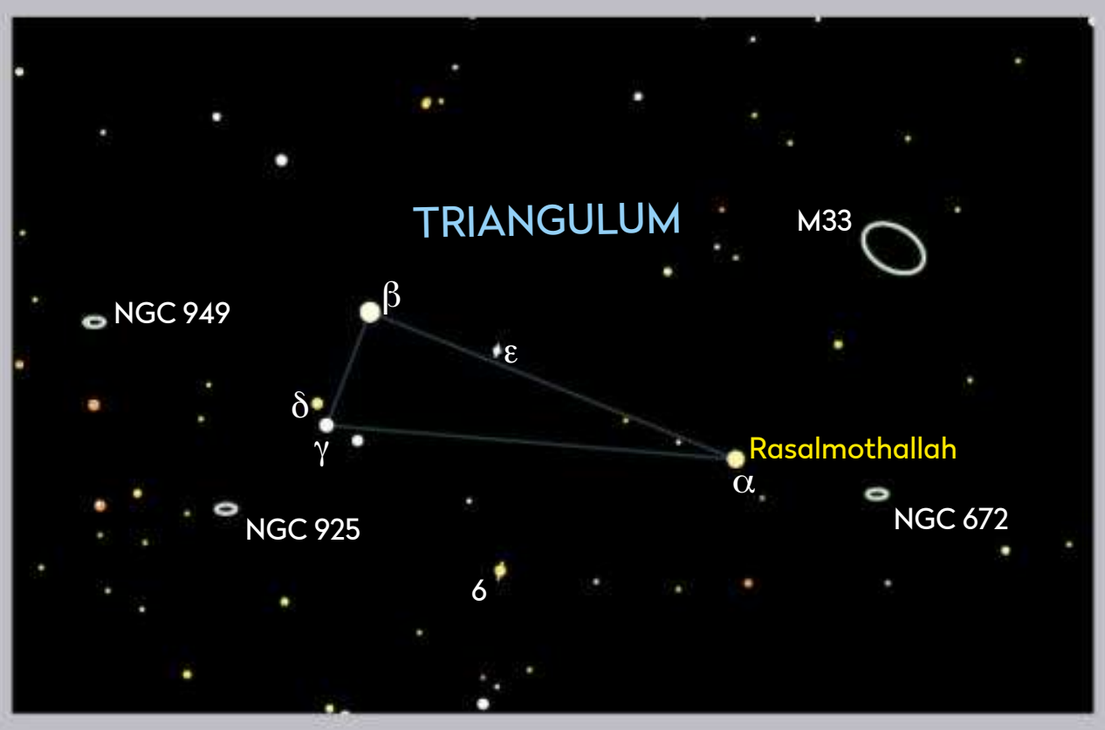
The comet was discovered by Klim Ivanovich Churyumov while examining a photo taken by Svetlana Ivanovna Gerasimenko on 11 September 1969.

► **Read more about 67P Rosetta in our feature on page 66.**

STAR OF THE MONTH

Rasalmothallah, at Triangulum's point

▼ **Rasalmothallah marks the pointed, western end of Triangulum**



Rasalmothallah (Alpha (α) Tranguli) is located in the small isosceles triangle of stars known as Triangulum, the Triangle. It is a curious constellation, because it could be argued that any three stars form a triangle, unless they're in a line! There's a southern equivalent too, Triangulum Australe, the Southern Triangle. In mythology the northern version represents the island of Sicily, but sadly the southern variant has no mythology of its own. Rasalmothallah marks the western end of Triangulum.

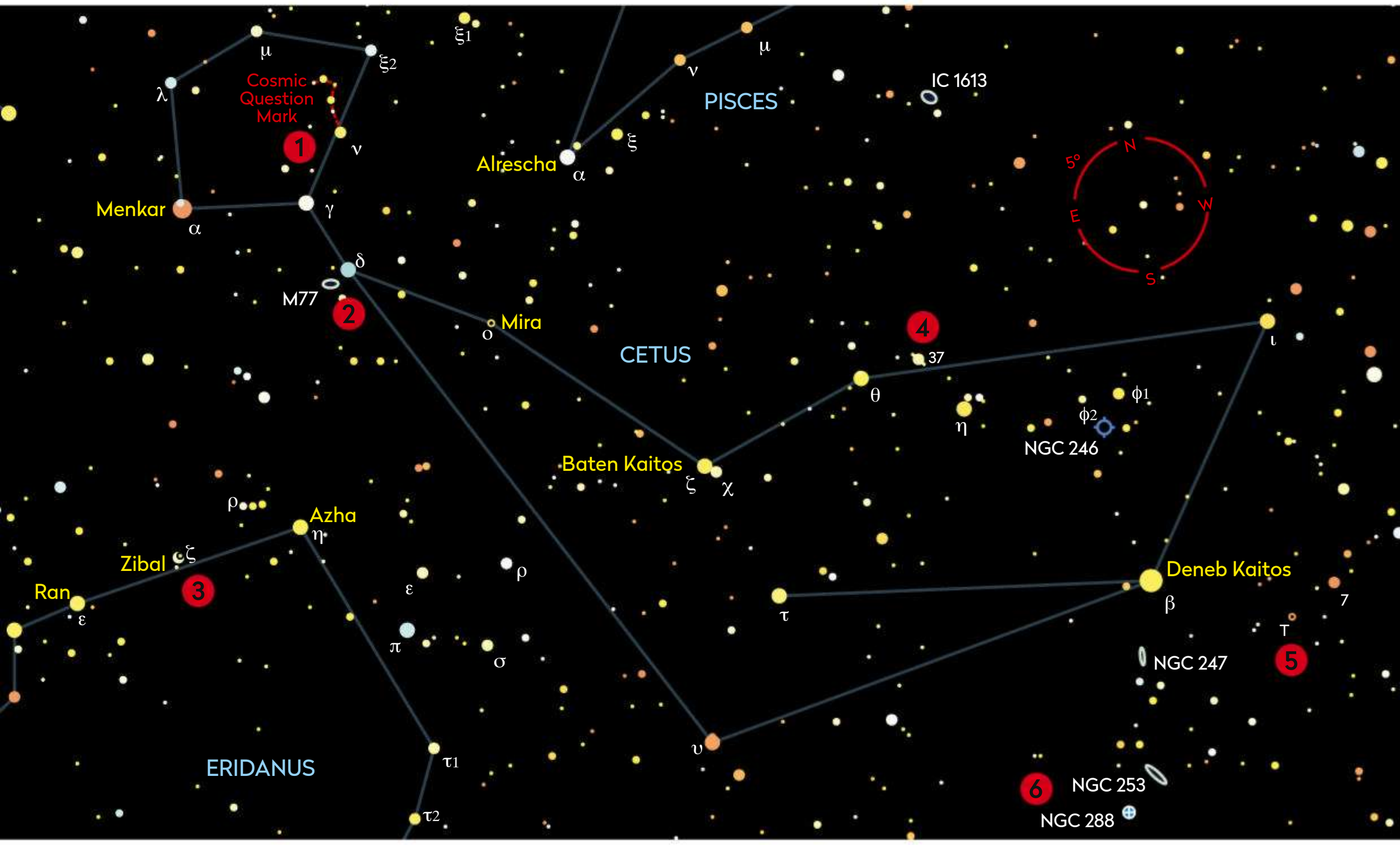
The 'Rasal' portion of the name may sound familiar. The two most common examples of its use are in the star names Rasalgethi and Rasalhague, two stars representing the heads of Hercules and Ophiuchus respectively, so you may have guessed that this means 'head'. The name Rasalmothallah means 'head of the triangle', something echoed by its now defunct name Caput Trianguli. Caput means 'head' in Latin, another example being Serpens Caput, the Serpent's Head. It's worth noting that the International Astronomical Union Working Group on Star Names (WGSN) set up in 2016, approved the revised name Mothallah for Alpha Trianguli – robbing the triangle of its head!

The star itself shines at mag. +3.4, lies at a distance of 63.3 lightyears from the Sun and is a spectroscopic binary. The components rotate around their common centre of mass once every 1.736 days. Analysis gives the system a spectral classification ranging from F5 III to F6 IV. F5-F6 puts it in the middle of the yellow-white colour temperature range of 5,720–7,220°C. III-IV indicates a giant or sub-giant. The primary rotates quickly at 81.6 km/s and its shape is most likely to be ellipsoidal as a consequence.

The gap between both stars is likely to be rather small, in the order of 0.04 AU.

BINOCULAR TOUR With Steve Tonkin

The wide-field treasures include double star Zibal and the Silver Coin Galaxy



1. The Cosmic Question Mark

10x 50 Nu (ν) Ceti is the dot at the bottom of the 2¼° long question mark that, when it is in the south of the sky, extends straight up above it. Four 6th magnitude yellowish stars make the curved part of the question mark, and the 7th magnitude star in the middle of the upright is a hot brilliant white colour that contrasts nicely with the rest of the Cosmic Question Mark asterism. ☐ **SEEN IT**

2. M77

15x 70 M77 lies slightly less than 1° east of Delta (δ) Ceti. It's a Seyfert galaxy, which means that most of its light comes from gas spiralling into its central black hole. This makes it quite easy to see the nucleus, but any skyglow will obscure the galactic disc, making the galaxy look star-like in binoculars. If you intend to try a Messier marathon next spring, practise finding the M77 galaxy, which is an early twilight object. ☐ **SEEN IT**

3. Zibal

10x 50 Let's continue with a nice easy double star. Zibal (Zeta (ζ) Eridani) is a pure white star that shines at mag. +4.8. To the northwest, 5 arcminutes away, is its mag. +6.6 companion. This is a chance line of sight pairing, not a true binary; the golden companion appears 1.8 magnitudes fainter than Zibal, but it is more than four times as distant and this conceals another reality: it is intrinsically 1.6 magnitudes more luminous. ☐ **SEEN IT**

4. 37 Ceti

15x 70 The double star 37 Ceti lies 2.5° west of Theta (θ) Ceti. Its components are 49 arcseconds apart, which should be an easy split even with lower magnifications, but the magnitude of the companion is only mag. +7.9, which is 13 times less bright. This magnitude difference can make it tricky to split, which is why we are using larger binoculars that should be mounted for steadiness. ☐ **SEEN IT**

5. T Ceti

10x 50 Identify 7 Ceti and navigate 2° to the southeast, where by far the reddest star in the region is the semi-regular variable (mag. +5.0 to +6.9) T Ceti. It is a red giant that has technetium in its spectrum. The most stable isotope, Tc98, has a half-life of 4.2 million years. This is much shorter than the billions of years age of the star and provides incontrovertible evidence for stellar nucleosynthesis. ☐ **SEEN IT**

6. The Silver Coin Galaxy and NGC 288

10x 50 Nearly 5° south of Diphda (Beta (β) Ceti), you will find a right-angle of 5th magnitude stars, below which is a rhombus of fainter stars. NGC 253, the Silver Coin Galaxy, is an elongated glow nearly 1° southwest of the rhombus. Now look about 2° in the direction of Alpha (α) Sculptoris, where you should see the glow of globular cluster NGC 288. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Can you separate bright Capella's two true companion stars from the impostors?

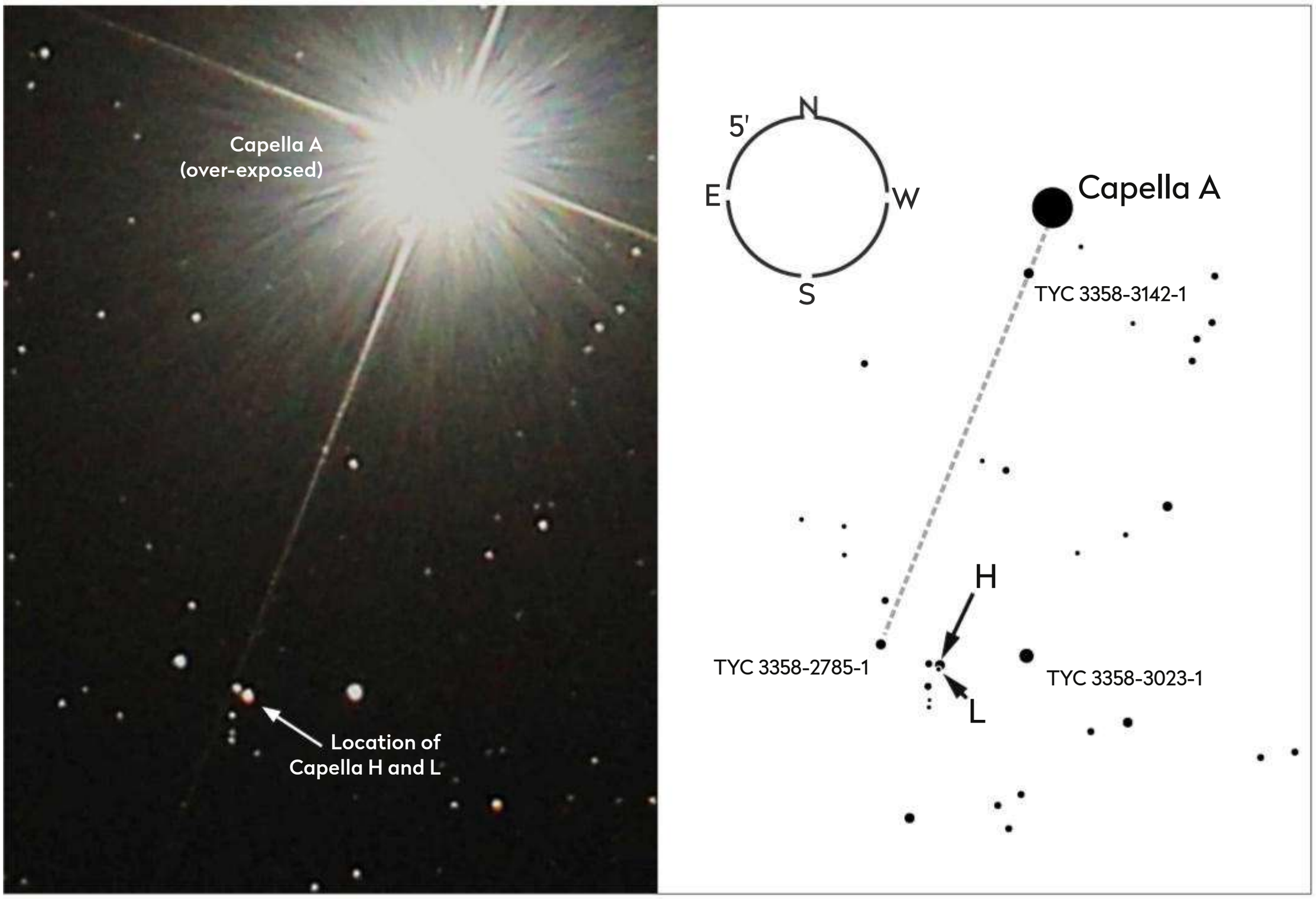
Capella (Alpha (α) Aurigae) rides high across the winter sky, a yellow beacon at the top of the misshapen pentagon that represents the main part of the constellation of Auriga, the Charioteer. Look at Capella through a telescope and you'll see numerous other stars nearby. These are listed in the *Washington Double Star Catalogue* as Capella A (the main star) through to Capella R. Of these, only two are known to be true physical companions, Capella H and Capella L. The others appear close simply because they occupy the same line of sight as Capella A. This month's challenge is to locate Capella H and possibly Capella L.

The main star, Capella A, is a spectroscopic binary, Aa and Ab, two yellow giant suns in a 104-day mutual orbit around one another. Their mean orbital distance is around 0.74 AU, which is approximately the distance between Venus and the Sun. At a distance of 42.8 lightyears, amateurs can't see these stars separated, and they appear as one.

Capella H and L are different and are viable targets for amateur telescopes. The stars are a binary pair of red dwarf stars gravitationally linked to Capella Aa and Ab, thus forming a quadruple system. While Capella A is easy to find with any size of telescope, Capella H needs at least 150mm of aperture and Capella L a 250mm scope. A large instrument over 300mm in aperture is recommended to separate the pair convincingly

Capella H and L appear very close to one another in the night sky, separated by just 3 arcseconds. They sit 12 arcminutes southeast of Capella A, between two field stars, mag. +10.0 TYC 3358-2785-1 and mag. +8.7 TYC 3358-3023-1. This makes Capella H easier to locate. Start with a low- to mid-power eyepiece giving you a field of view at least 30 arcminutes across; that's roughly the apparent diameter of the Moon. Centre on bright Capella A, then identify mag. +10.2 TYC 3358-3142-1, 1.7 arcminutes southeast of Capella A. This is a key navigational star for two reasons. Its brightness is the same as mag. +10.2 Capella H and if you can see easy-to-find TYC 3358-3142-1, you should be able to see H. Secondly, a line from Capella A through TYC 3358-3142-1 points to TYC 3358-2785-1, mentioned earlier.

Once you've located TYC 3358-2785-1 you should be able to identify brighter TYC 3358-3023-1 quite easily. There are several faint stars between TYC 3358-2785-1 and TYC 3358-3023-1, Capella H being the brightest one, roughly mid-way between them. Once identified, increase magnification to see whether you can see a southern 'extension' to Capella H. If you can, you've located Capella H's close binary companion, mag. +13.7 Capella L. Imaging the pair really helps reveal the distinct orange hue of this red dwarf binary.



▲ **Locate Capella H (and the more tricky Capella L) by finding it mid-way between two field stars, as shown in the locator chart (right)**

DEEP-SKY TOUR

This month's tour visits objects in Taurus, some familiar and others less so

1 M45

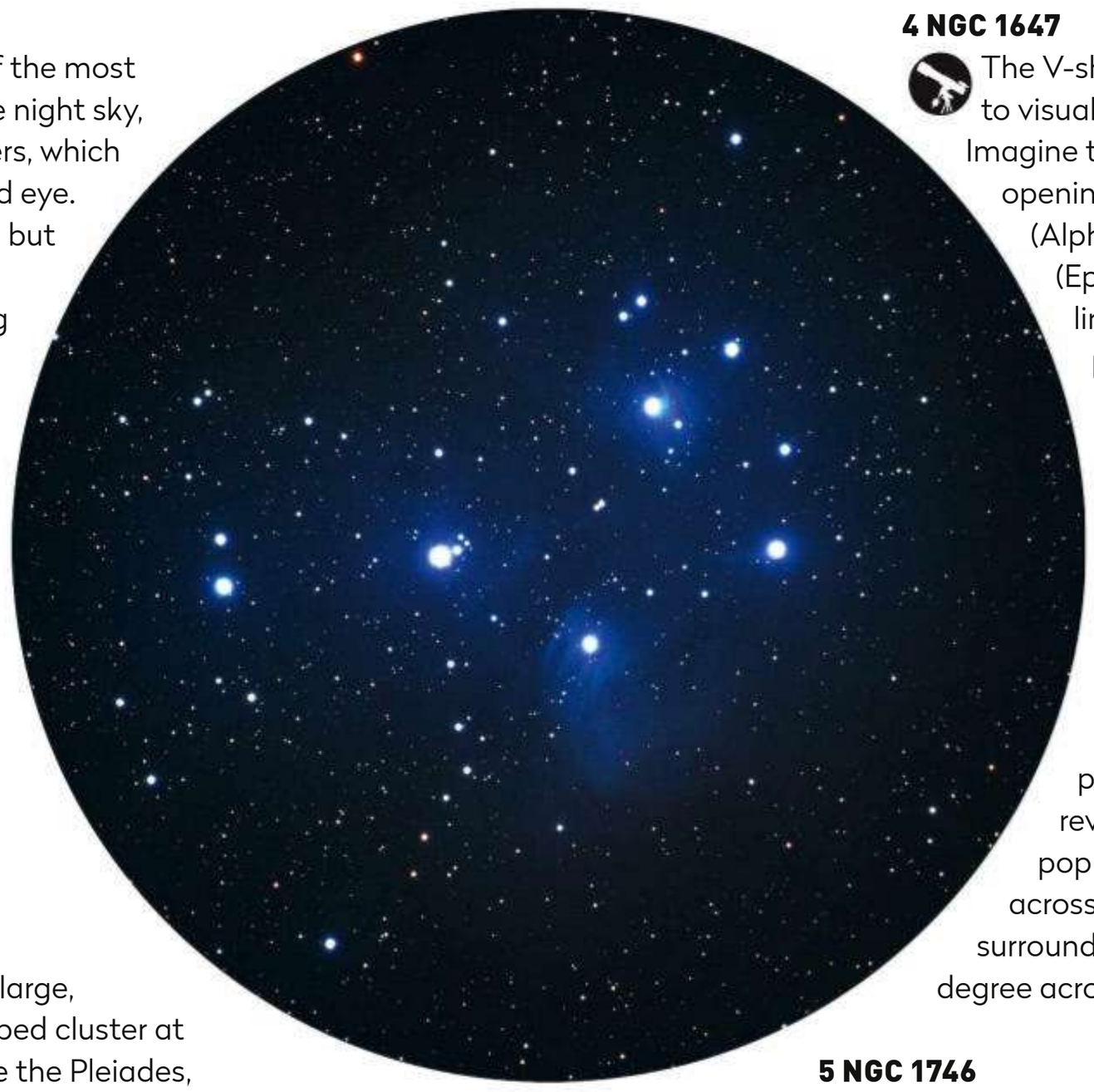
We'll start with one of the most familiar clusters in the night sky, the Pleiades, or Seven Sisters, which is easily visible to the naked eye. Binoculars bring it out well, but you'll need to use a low power eyepiece when using a scope, otherwise you'll look right through it. The sheer number of stars revealed with a scope is a joy to behold. If you have dark skies, look out for the misty nebulosity within the cluster, most notably NGC 1435 around Merope (23 Tauri), the southernmost star in the main box shape within the cluster. ☐ **SEEN IT**

2 The Hyades

The Hyades is a large, sideways, V-shaped cluster at the heart of Taurus and like the Pleiades, requires a low power eyepiece to see it properly. There are a number of treats in and around the Hyades, including various telescopic doubles such as 80 and 81 Tauri, Delta-3, Struve 545 and 559. Larger apertures may like to look for Sharpless 2-239, a 13th magnitude oval-shaped reflection nebula occupying an area about 5 arcminutes across. A short distance to the north of the cluster lies NGC 1555, which is known as Hind's Variable Nebula. It appears as a faint glow to the west of 10th magnitude star T-Tauri, varying in brightness thanks to T-Tauri's variability. ☐ **SEEN IT**

3 NGC 1615

This region of the sky is rich in local deep-sky objects embedded within the Milky Way and you wouldn't normally associate it with external galaxies. There are some to be had though, including NGC 1615, which lies 1.9° to the east-northeast of Ain (Epsilon (ε) Tauri), the most northerly star in the Hyades' sideways V. The galaxy is an S0 class lenticular galaxy, shining at mag. +13.7. A 300mm scope will show it as a faint glow about 50 x 30 arcseconds across, its circular core visible with direct vision, although the outer halo requires averted vision. ☐ **SEEN IT**



▲ The Pleiades cluster lies at a distance of 444 lightyears and contains an estimated 3,000 members

4 NGC 1647

The V-shape of the Hyades is easy to visualise with the naked eye. Imagine the two stars at the opening of the V, Aldebaran (Alpha (α) Tauri) and Ain (Epsilon (ε) Tauri) as a mirror line. Reflect the star at the point of the V, Gamma (γ) Tauri, and the position you arrive at marks NGC 1647's location, an open cluster easily viewed with a small scope.

A 150mm scope reveals almost 50 stars within a 45-arcminute region, many arranged in pairs. A 250mm scope reveals a more densely populated core, 30 arcminutes across, with the less populated surrounding area extending to a degree across. ☐ **SEEN IT**

5 NGC 1746

The arms of the Hyades extend towards two stars, marking the Bull's horn tips; Elnath (Beta (β) Tauri) and Zeta (ζ) Tauri. Approximately midway along the northern extension towards Elnath and slightly south is open cluster NGC 1746, which makes a good comparison with NGC 1647. NGC 1746 generally contains fainter stars, with the exception of half a dozen brighter ones across the area. A 150mm scope shows a haze of around 75 stars within a 30-arcminute region at the cluster's centre.

However, things aren't as they seem here, because the region contains three NGC objects; NGC 1746, 1750 and 1758. There's also a question as to whether NGC 1746 is actually NGC 1750 or perhaps a separate cluster inside 1746. NGC 1750 overlaps with 1748. If you have the impression you're seeing more than one cluster here, you probably are! ☐ **SEEN IT**

6 M1

M1, the Crab Nebula, lies near the star marking the Bull's southern horn tip, Zeta (ζ) Tauri. The first entry in Messier's catalogue is fairly well known, the Crab Nebula representing the remnants of a star which was seen to explode in AD 1054. A 150mm scope shows an elongated haze, 5 x 3 arcminutes across. Its oval shape appears mottled and it's possible to make out a rough 'S' shape formed from the brighter mottles. The nebula appears uneven in brightness, the northwest half brighter than the rest. M1 is sometimes described as appearing like a faint comet with a short tail. ☐ **SEEN IT**

IMAGES, CHART BY PETE LAWRENCE
VIKTAR/ISTOCK/GETTY

This Deep-Sky Tour has been automated ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.

AURIGA
PERSEUS
ARIES
TAURUS
NGC 1778
M38
NGC 1907
IC 405
NGC 1931
M36
NGC 1893
Hassaleh
ι
Kohoutek 2-1
Elnath
β
IC 2003
IC 348
NGC 1514
05h00m
04h00m
+30°
+20°
+10°
N
E
S
W
5°
2°
IC 2087
Alcyone
η
Pleiades
(M45)
1
NGC 1746
NGC 1758
NGC 1750
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τ
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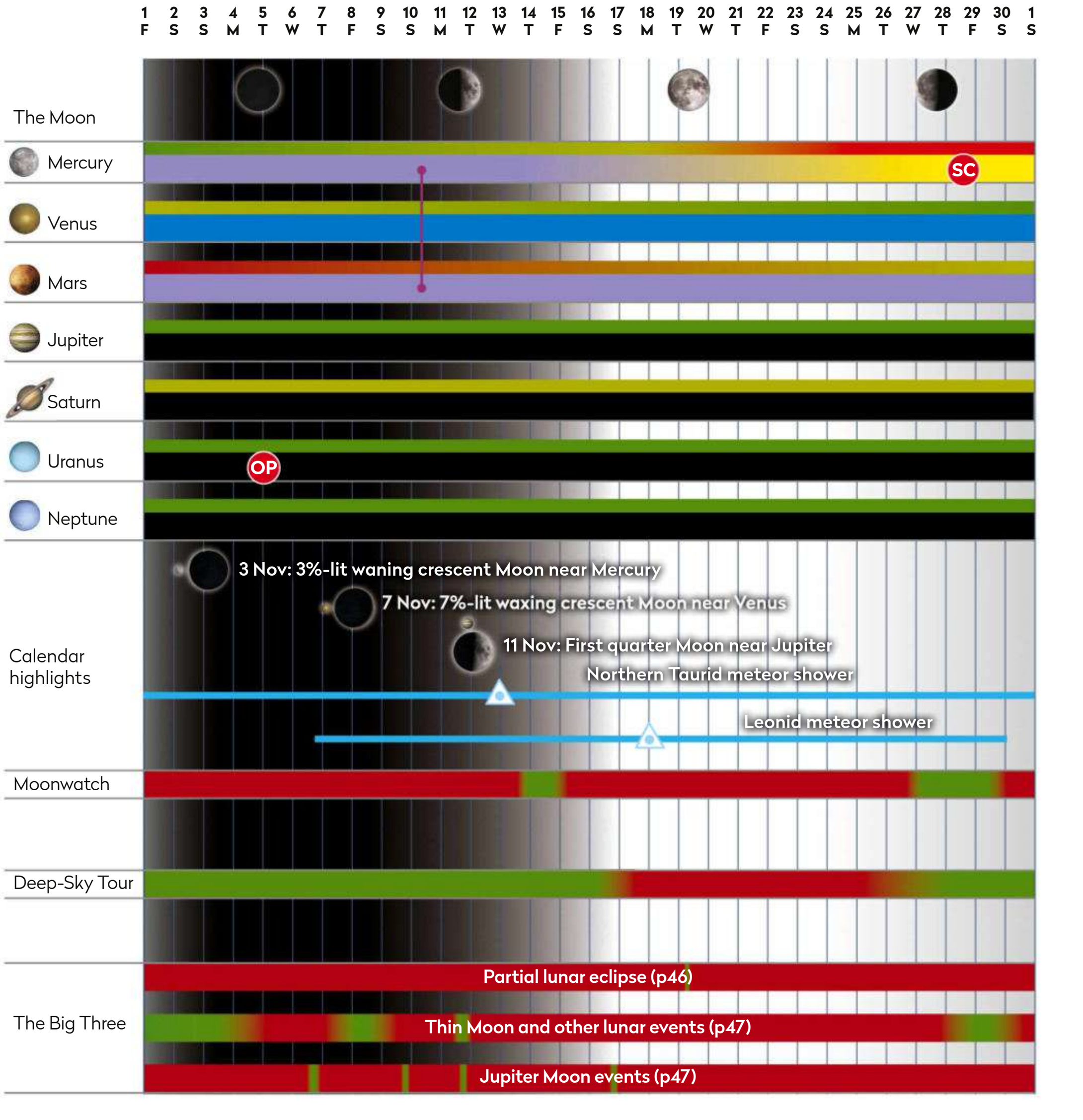
3
NGC 1555
Struve 545
NGC 1615
Ain
ε
Sh 2-239
δ1
δ3
δ2
NGC 1647
4
Struve 559
Hyades
(Melotte 25)
2
θ1
α
Aldebaran
γ
81
80
π
θ2
λ
σ1
σ2
ρ
6
M1
ζ
Collinder 65
NGC 1817
NGC 1807

AT A GLANCE

How the Sky Guide events will appear in November



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE

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WILL GATER

The lunar 'ray ejecta' – the ancient material thrown out by crater-forming impacts – can tell stories about the history of our nearest neighbour

RAYS of INSPIRATION

The Moon is pockmarked with spectacular splashes from ancient impacts. Astronomer **Will Gater** shows you how to observe and image them

The face of the Moon today records hundreds of millions of years' worth of asteroid and comet impacts – its disc is peppered with countless craters and large basins, where immense collisions punched deep into the lunar crust. But scattered across the Moon's pockmarked highlands and smooth basalt seas emanating from some craters are also striking, bright features. They are cosmic splashes of rock and dust that give a hint of the dynamic and tumultuous past of our nearest neighbour.

Astronomers call these surface features 'ray ejecta' – the material thrown out from the impacts that made their parent craters. These dazzling ray systems are generally associated with younger craters. Tycho, for example, is thought to have formed around 109 million years ago. The bright streaks are, in essence 'fresher', material that hasn't experienced the same level of space 'weathering' as its surroundings – a process that typically darkens the surfaces of Solar System bodies.

The impact events that created these ray systems must have been breathtaking. Though we can't see ▸

The numerous ‘ray ejecta’ across the lunar surface are best seen around full Moon

▸ those cataclysms today, viewing some of the ejecta they left behind through a telescope or a good pair of binoculars can still give one an appreciation of the immense energy involved.

Pick your time

One interesting aspect of observing ray ejecta on the Moon is that they come to prominence at a time during the lunar cycle when other targets are poorly illuminated for observation or imaging. Craters, mountains and rilles appear most spectacular when they’re obliquely lit – something that accentuates surface textures and differing heights with deep shadows. Ray systems, though, appear at their most impressive when the Sun is high over their location on the lunar surface. In fact, most ray systems become almost invisible when their parent craters are lit from a shallow angle. This means that full Moon and the late gibbous phases, when features on the far eastern or far western side of the lunar disc are lit from above, are the best times to see these enigmatic ray ejecta.

Some ray ejecta systems, like the sprawling mass that surrounds the crater Copernicus, can just be made out with the naked eye on a clear night. A good pair of binoculars is also a wonderful way to explore them. At full Moon, when the air is still, the view of Tycho’s extraordinary rays in 10x50 binoculars gives a real sense of the huge streaks of ejecta material wrapping ‘around’ the three-dimensional hemisphere of the Moon’s nearside.

Indeed, their ease of viewing is something that makes the ray systems unlike many of the smaller features on the lunar disc. What’s more, to explore the largest ray ejecta features in more detail you really don’t need a large telescope; a small refractor ▸

ALL PICTURES: WILL GATER

An inverted vision

How to capture and process an image of the lunar ray systems with a twist

Sometimes it pays to look at things in a completely new way in order to see them in a different light and appreciate them anew.

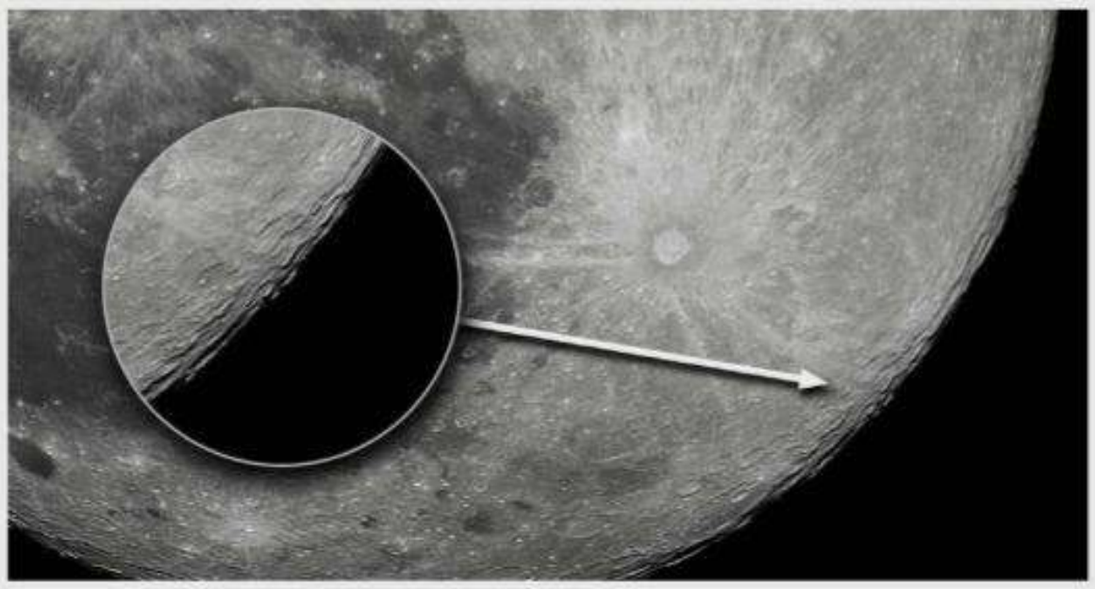
There’s a striking processing technique you can try that turns our regular view of the lunar disc on its head. Put simply, you invert the colours of the Moon so that light features (like ray ejecta) become dark while dark features become light. What’s so great about this method is that it’s something that can be done with a range of lunar imaging styles and equipment levels; you can do it holding a smartphone up to a scope’s eyepiece or with advanced mosaics of the whole disc. For the best results, try it at full Moon or during the late gibbous phases of the lunar cycle.

The process itself is the same as taking any other Moon image: you try to get the clearest, sharpest and best-exposed image of the whole disc. It’s in the processing that things are different.

You’ll need an image editing program that can apply an inversion filter. Once you’ve captured your image, open it in your editor and then ‘desaturate’ it so it’s in ‘grayscale’. Then apply an inversion filter to the whole image. In Photoshop this is done by selecting ‘Image’ > ‘Adjustments’ > ‘Invert’. Next, tweak the brightness and contrast with the ‘Levels’ to make the ray systems stand out.

High resolution rays

Catch ray ejecta systems with a high frame-rate camera and a telescope



STEP 1

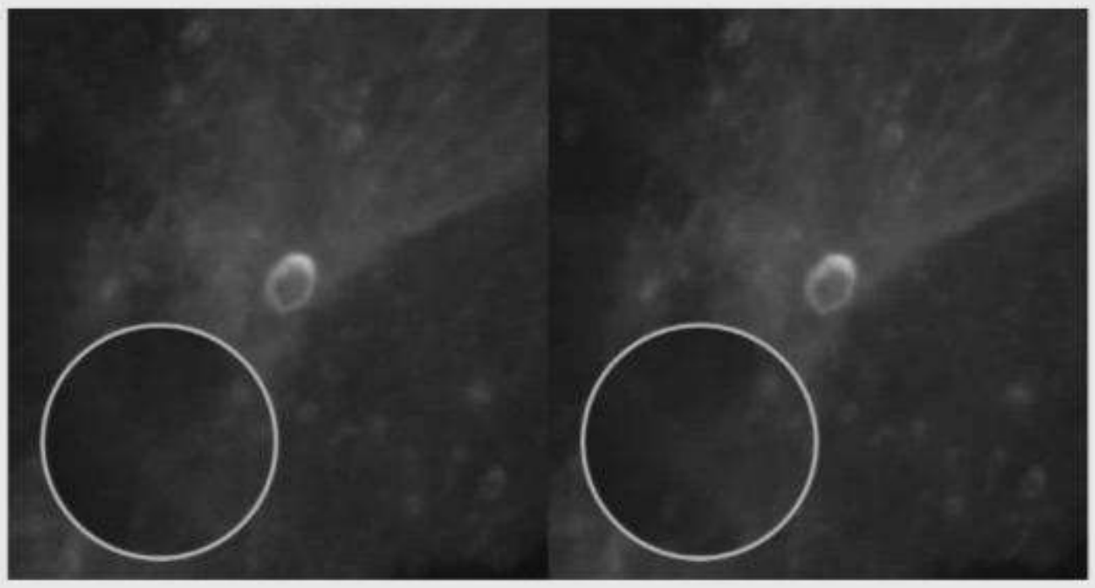
Find the right illumination for your target

Lunar features change appearance dramatically with varying illumination, and ray systems are no different. While craters look interesting when lit obliquely, ray ejecta appear far more striking – and more visible – when the Sun is high above them. To get the best images, plan your imaging sessions for nights when these features are located away from the terminator.

STEP 2

Use the lunar limb or terminator for focusing

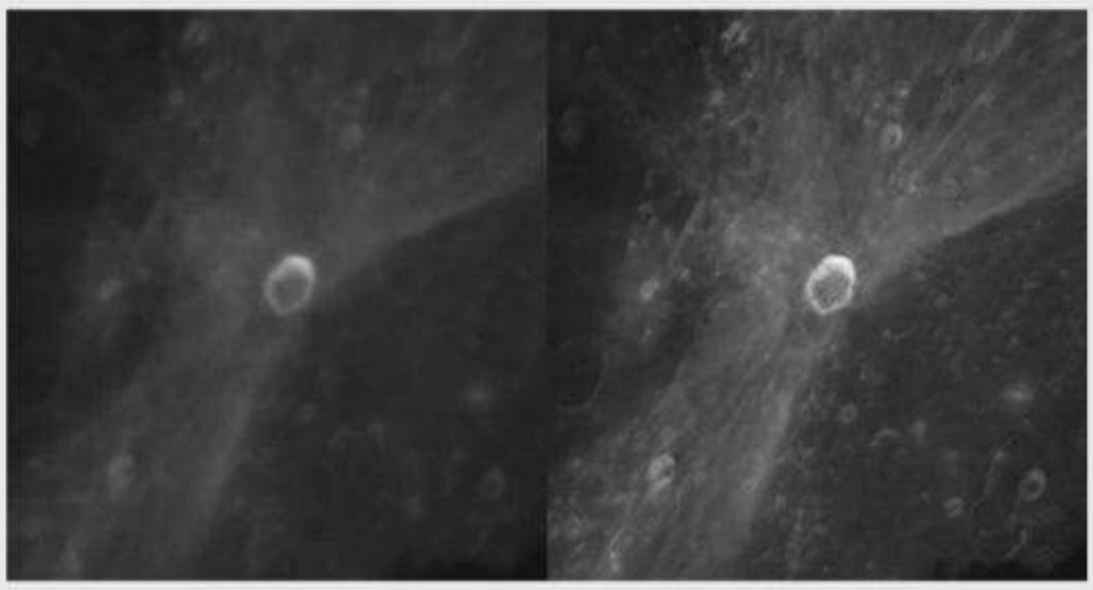
Without shadows contrasting with bright edges as you'd find on obliquely-lit lunar features, focusing your camera on a ray system that's lit from a high angle can be tricky. Point your scope over to the terminator, focus there and move back; even if the Moon's 'full' there will often be obliquely-lit craters near the limb which you can focus on before framing up your target nicely.



STEP 3

Don't blow out the highlights

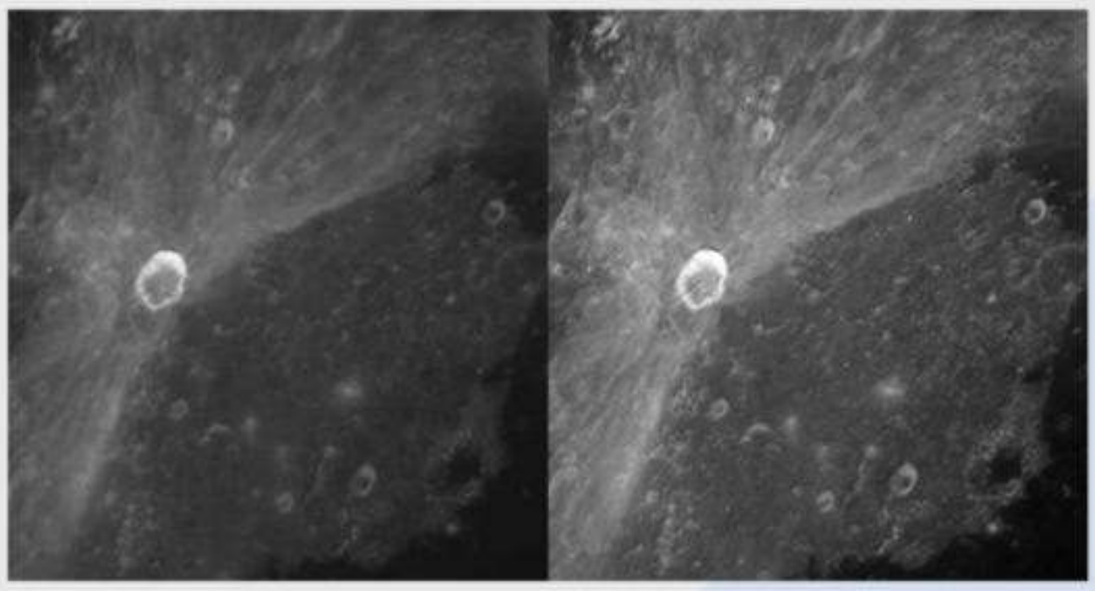
Ray systems are bright features and we need to take extra care when we set the camera's exposure level. If you overexpose the rays you won't capture their fine structure in detail, as the highlights will be 'blown out' and unrecoverable in post-processing. A basic way to avoid this is to make sure that nothing in the frame appears near to solid white in the imaging preview.



STEP 4

Generate a smooth stack

We're going to apply sharpening and enhancements to our final picture, so we now need to create a smooth starting image – one in which the noise 'graininess' that you see in a single frame is reduced. Take a short AVI-format video of your target consisting of a few thousand frames and run it through AutoStakkert! or RegiStax, which will identify and stack the best frames.



STEP 5

Bring out the detail with 'Wavelets' sharpening

The image created at the end of Step 4 should be smooth, but will look a little soft, so we now need to make the crucial sharpening adjustments in RegiStax to make the ejecta details 'pop'. Open the image and tweak the top three sliders on the left hand side of the 'Wavelets' tab. Pay attention so you don't over-sharpen, where noise starts to overwhelm fine details and the view looks crunchy.

STEP 6

Use 'Curves' tweaks to improve contrast and definition

Apply contrast and brightness adjustments in an image editor to make the ray systems stand out; the 'Curves' tool is good for this as it allows for greater control of which tones are being tweaked. You can duplicate the image as another layer and apply a gentle 'High Pass' filter; then blend the filtered layer with the original layer using a 'Soft Light' mode to improve the latter's definition.

Excellent ejecta

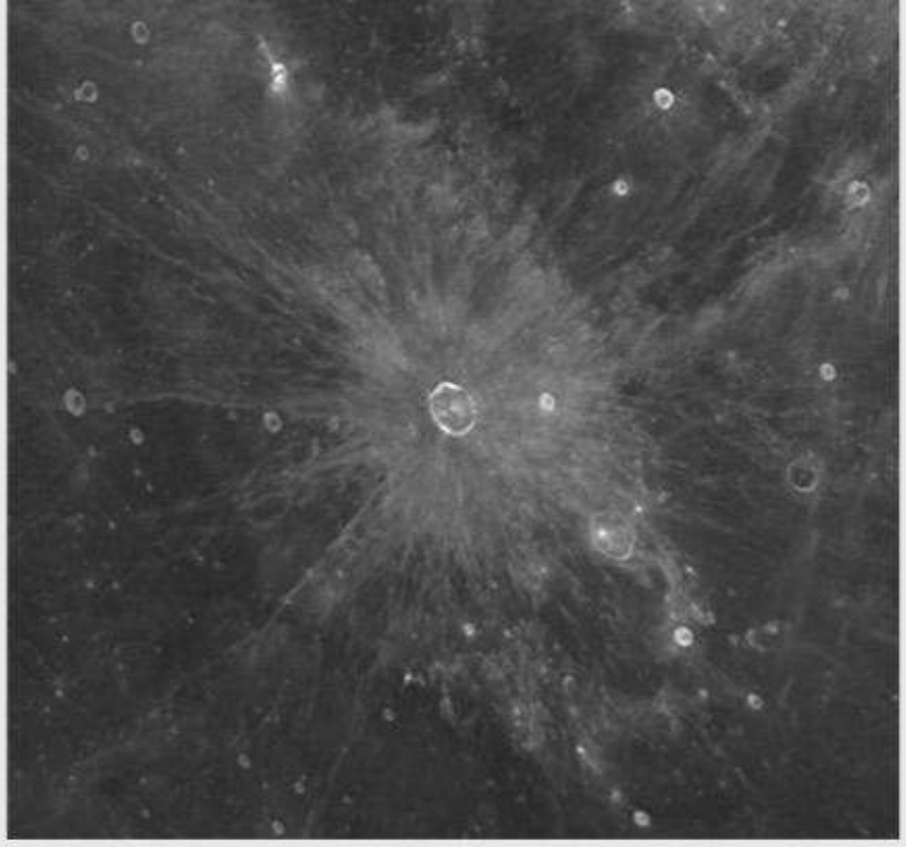
We select six of the best lunar ray systems you can observe with either binoculars or a small telescope

▲ COPERNICUS

Copernicus is a magnificent crater that has an extensive ray system surrounding it that's every bit as impressive as its terraced walls and towering central peak mountains. The crater's bright ejecta blanket can be perceived with the naked eye when the Moon is full or in a late gibbous phase, but to explore the intriguing wavy nature of the rays you'll need a small telescope of 4–6 inches (100mm–150mm) in aperture.

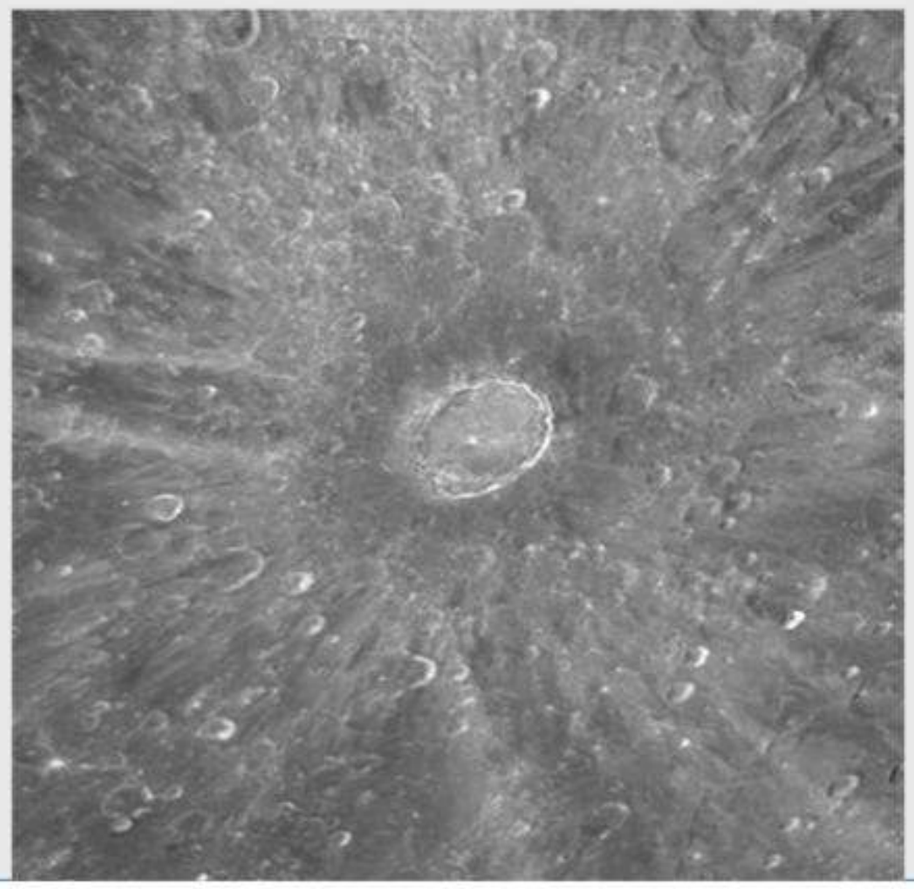
TYCHO ▶

The crater Tycho possesses, undoubtedly, the most spectacular ray ejecta system on the Moon. Some rays from Tycho stretch most of the way across the lunar disc and dominate the rugged southern highlands, where Tycho sits. Binoculars will show the ray system and the bright ejecta blanket surrounding Tycho when sunlight is shining from a high angle onto the crater and its surroundings.



▲ KEPLER

A short hop from Copernicus is the similarly impressive crater Kepler. Though Kepler itself is smaller than Copernicus it nonetheless has a fine ray system that is a delight to explore with a large telescope using a medium magnification eyepiece. There's an interesting mix of forms visible within the rays, from some that shoot out radially in a fairly straight fashion, to others that have a slightly meandering appearance.

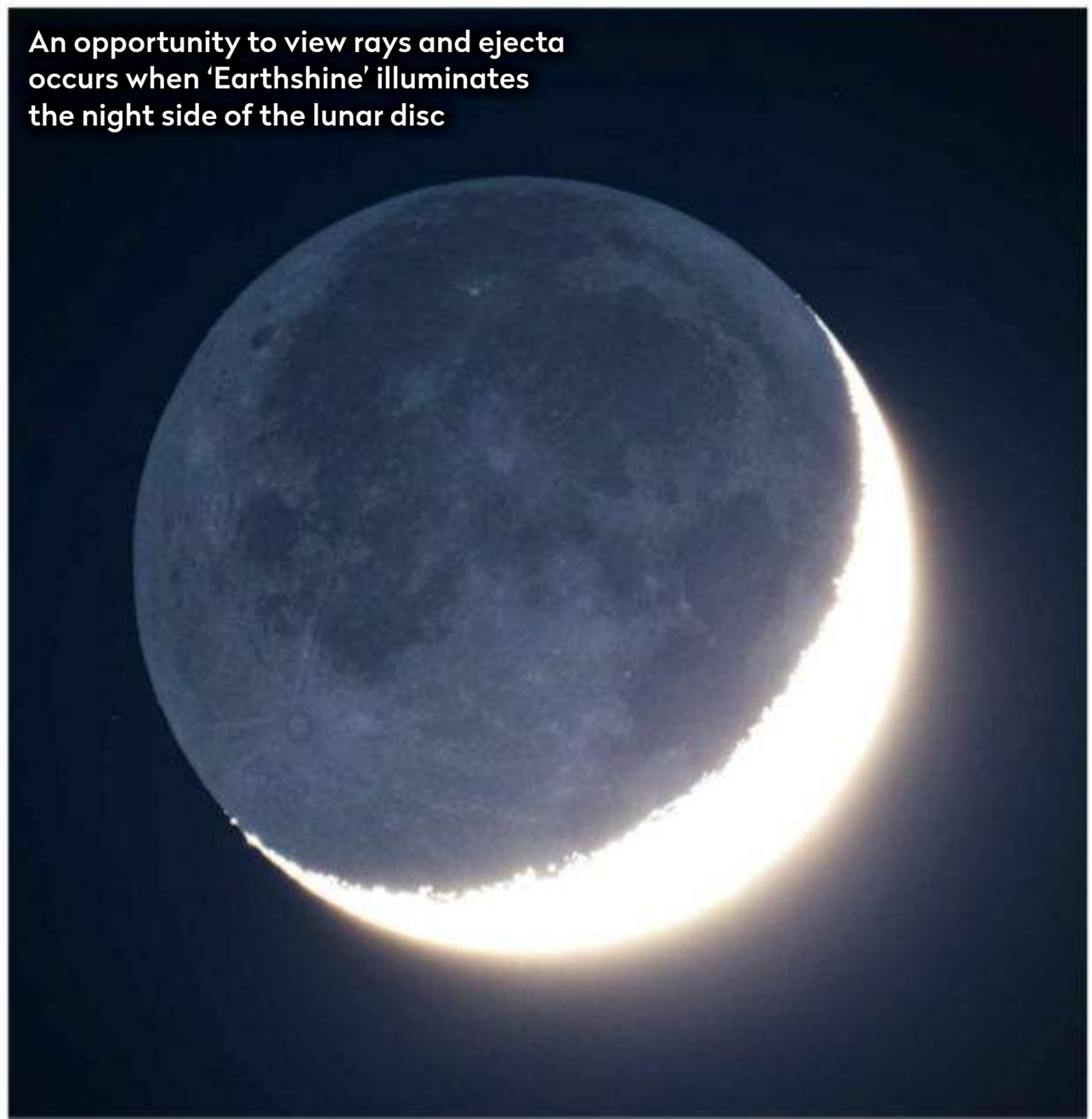


▸ with an aperture of around 60mm is perfectly suited to providing wide views of the streaked landscape around Copernicus, Kepler and Tycho.

You can even use a small telescope to look for the brighter ejecta regions when they are shrouded in lunar night. When the Moon is a thin crescent the light scattered off Earth illuminates the nightside of the lunar disc with 'Earthshine'. At these times, even though they are in darkness, the rays and ejecta blankets of craters like Aristarchus and Tycho still stand out clearly, lit only by our planet's glow.

Stunning ray systems

If you have access to a larger telescope, say 8–10 inches (200–250mm) in aperture, you'll be able to resolve finer details in the ray systems on nights of good seeing. A larger aperture instrument will also open up the smaller ray systems, such as the striking double streaks from the crater Messier and the fantastically shaped ejecta from the crater Proclus, which is likely to be the result of a shallow-angle impact. There are also a number of craters

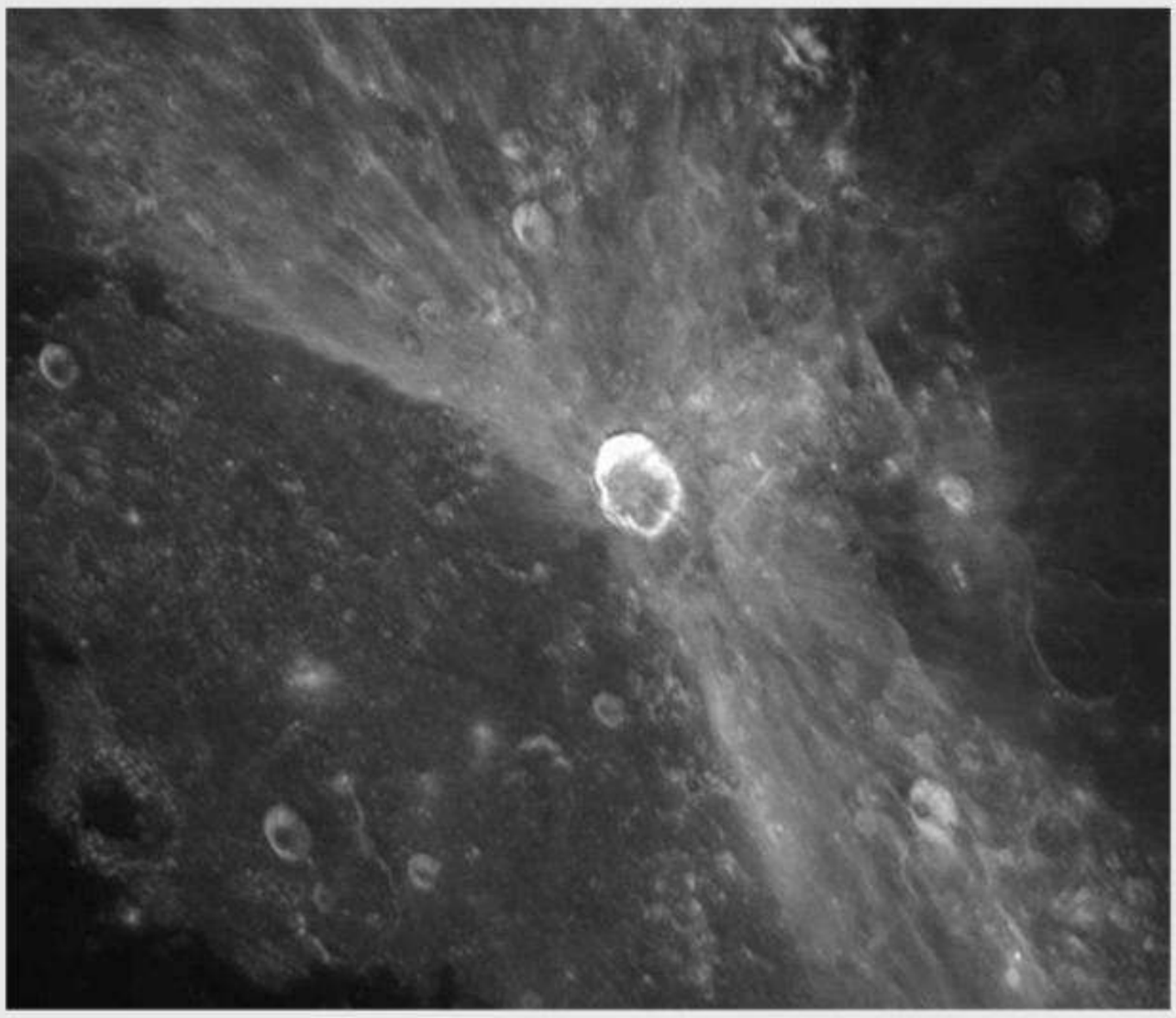


An opportunity to view rays and ejecta occurs when 'Earthshine' illuminates the night side of the lunar disc

ALL PICTURES: WILL GATER

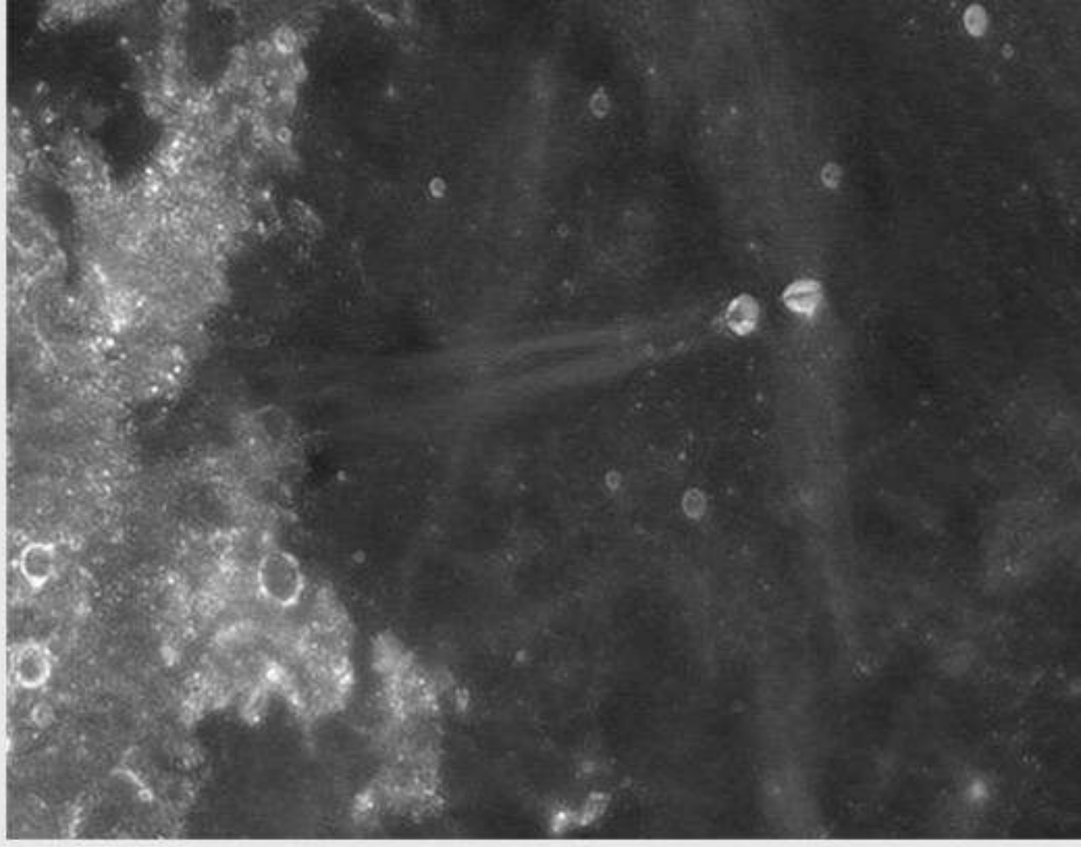
▼ PROCLUS

The 27km-wide crater Proclus lies in the cratered and hilly terrain that sits between the eastern shore of Mare Tranquillitatis and the curved western shore of Mare Crisium. The crater has one of the more unusual ray ejecta systems on the Moon – appearing somewhat like a handheld fan. The striking shape of the ejecta is visible in 10x50 binoculars and also makes it an interesting target for high-resolution imaging.



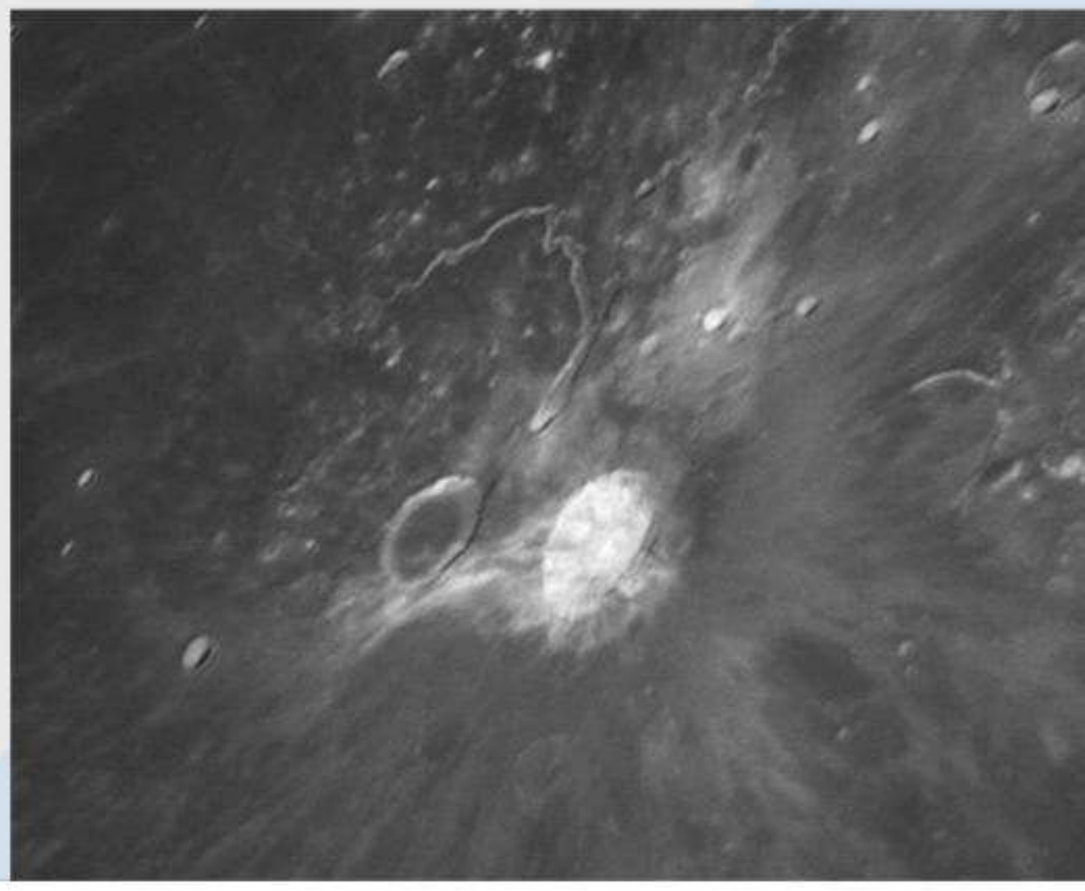
ARISTARCHUS ▶

Set within the vast Oceanus Procellarum, the crater Aristarchus cannot be missed around the time of full Moon as its dazzling inner walls are spectacularly bright and stand out conspicuously against the surrounding basalt plains. The crater also has an interesting ray system that spreads out in a filamented fan shape broadly towards the southeast. It makes for a fascinating target to explore with a telescope – either visually or with an imaging setup.



▲ MESSIER

When the Sun is high over the Mare Fecunditatis, a small telescope will reveal an intriguing ray system emanating from the twin craters of Messier and Messier A. The system's most prominent rays appear as two slightly diverging lines pointing towards the western edge of Mare Fecunditatis, and they stand out quite clearly against the darker lunar sea. The bright rays appear to stretch at least 160km, and may be even longer.



Pastel sketches, like this one of the crater Kepler, can be a great way of getting to know lunar ray systems

that have more modest ray systems around them, which are not quite as bright and showy as the most famous examples but are nonetheless fun to image or view at the eyepiece. Examples include those around the craters Aristillus, Langrenus, Anaxagoras and Petavius B.

Sketching with pencils or pastels can also be a great way to record views of lunar ray systems at the eyepiece. And that's indicative of what we love so much about these captivating features: there are many different ways to enjoy and explore them – binoculars, large scope, camera sensor or eyeball. Why not take one of our top picks and get started investigating them for yourself this month.

Will Gater is an astronomy journalist and science presenter. His latest book, *The Mysteries of the Universe*, is published by DK

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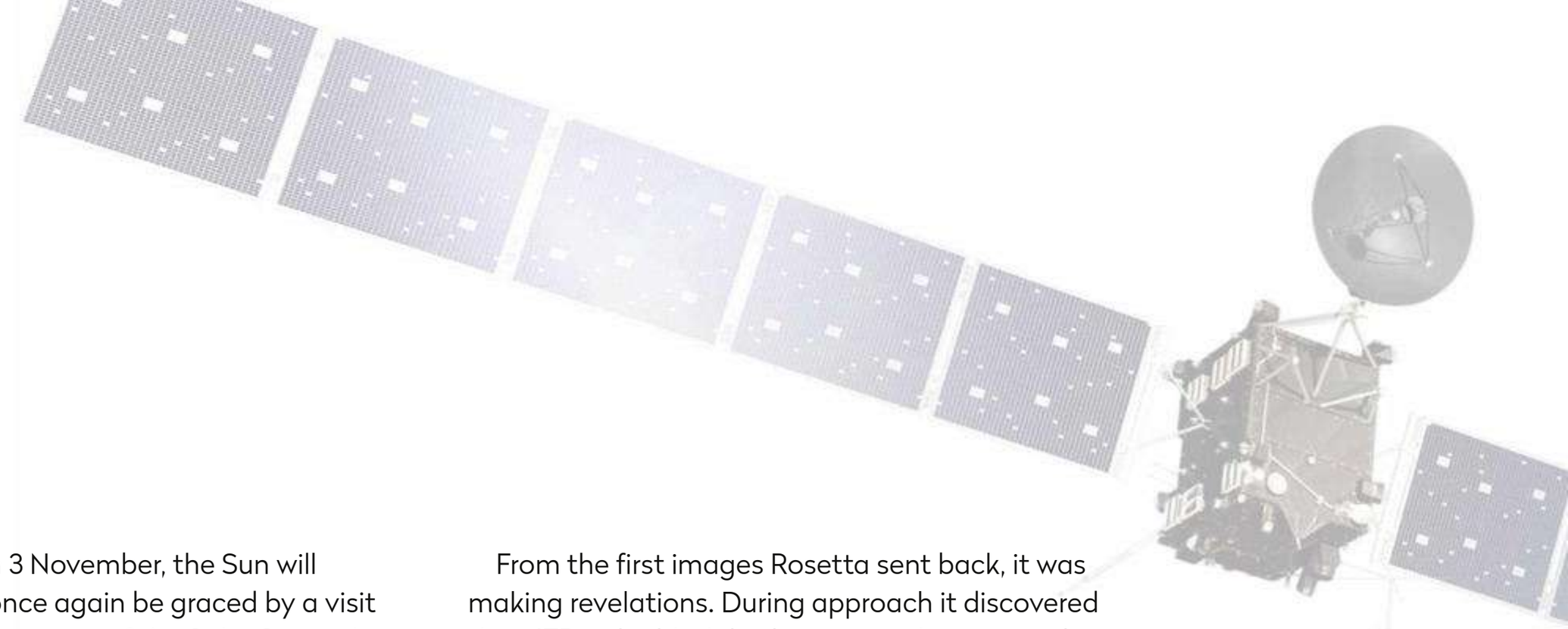
Remembering ROSETTA

As comet 67P/Churyumov-Gerasimenko reaches the closest position to the Sun in its orbit, **Ezzy Pearson** looks back at what the Rosetta mission taught us about our Solar System's icy wanderers

ESA/ROSETTA/NAVCAM, ESA

The Rosetta mission allowed us to touch down on comet 67P/Churyumov-Gerasimenko and begin to unlock the secrets of the early Solar System



ESA/C. CARREAU/ATG MEDIALAB X 2, ESA/ROSETTA/NAVCAM X 2, ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA X 2, ESA/ROSETTA/MPS

On 3 November, the Sun will once again be graced by a visit from one of the Solar System's frozen travellers – Comet 67P/Churyumov-Gerasimenko. Like all comets, 67P is a fragment left over from the creation of the planets; a time capsule containing a hint of what the Solar System was like during its formation 4.5 billion years ago.

By understanding comets, astronomers can piece together the history of our planetary system. So in 2004, the European Space Agency (ESA) launched a mission to 67P and began the most detailed exploration of a comet ever undertaken. The comet would act as a Rosetta Stone – a key that would allow them to unlock the secrets of all other comets – so the mission was called Rosetta.

Rosetta arrived at Comet 67P on 6 August 2014 and spent more than two years circling the comet as it drew closer to the Sun. The spacecraft watched the surface sublimate, turning straight from ice to gas, creating its beautiful tail. Its spectrometers examined the gas and dust coming off 67P to sniff out what chemicals were being released as the comet thawed. ESA even managed to set the washing machine-sized Philae lander down on the surface, making history as the first ever soft landing on a comet.

From the first images Rosetta sent back, it was making revelations. During approach it discovered that 67P is double-lobed comet, with two round sections stuck together in a formation many liken to a rubber duck. It was when Rosetta got into orbit around 67P that the real investigation could begin however, as the spacecraft was able to begin looking at every facet of the comet.

Water carrier

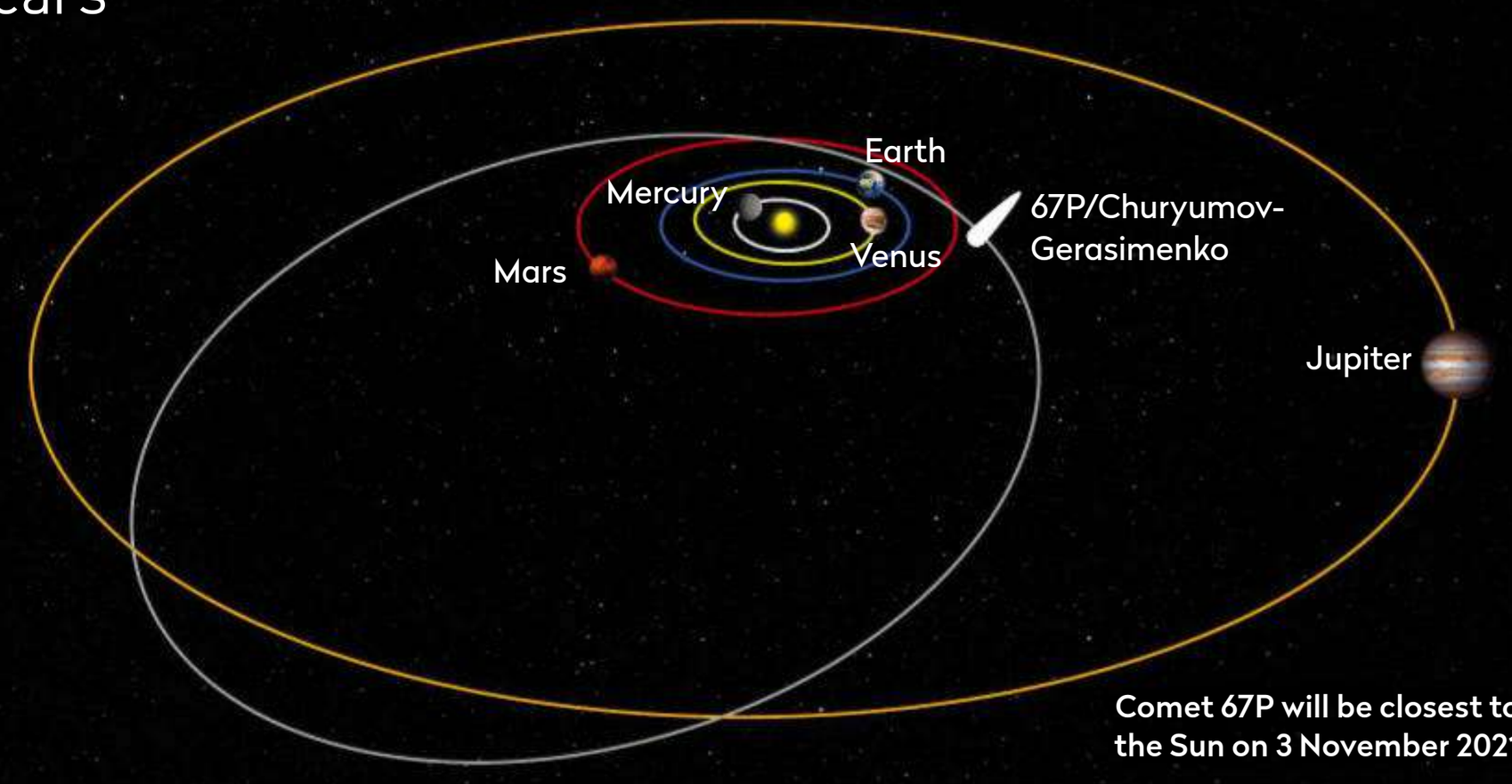
Many of Rosetta's instruments were focused on the swirling cloud of gas and dust surrounding the comet – its coma. One of the first measurements taken was the ratio of normal water to 'heavy' water, which contains an extra neutron. This ratio – known as the deuterium-to-hydrogen ratio or D/H – remains unchanged over time. As such, planetary scientists can use it to trace the movement of water over our Solar System's history. Planetary scientists have wondered for decades if comets brought water to the early Earth. If they did, then the D/H for comets should be the same as it is on Earth.

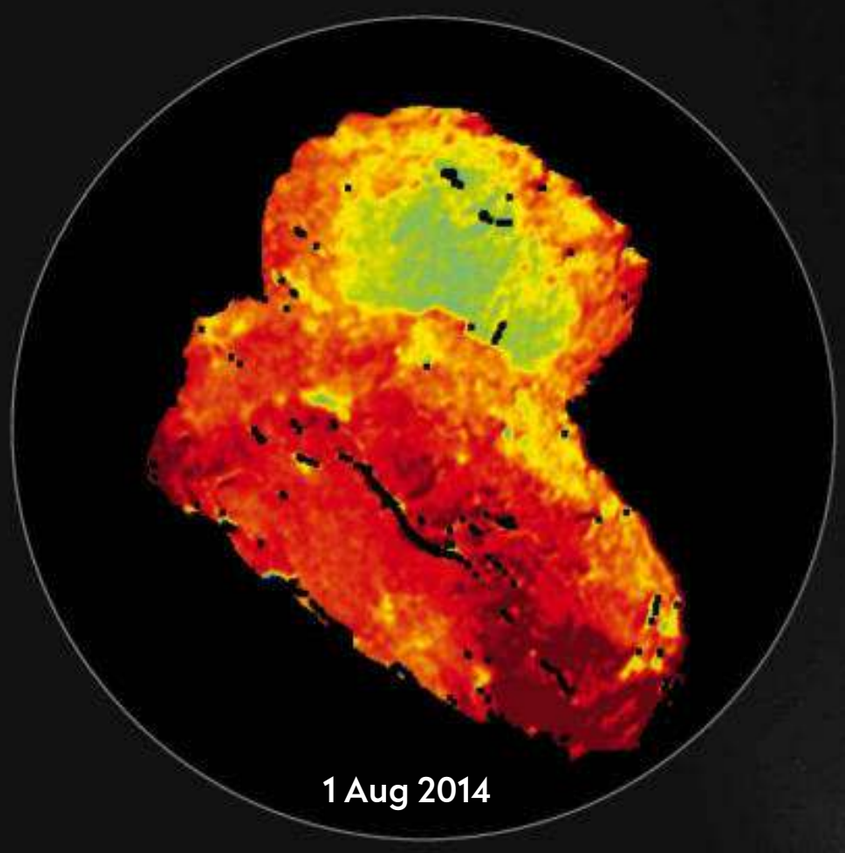
"The D/H was higher than any comet measured so far, which answered [the question of] whether our terrestrial water came from comets. And that answer is a no," says Professor Kathrin Altwegg, project manager of the Rosetta Orbiter Spectrometer for Ion

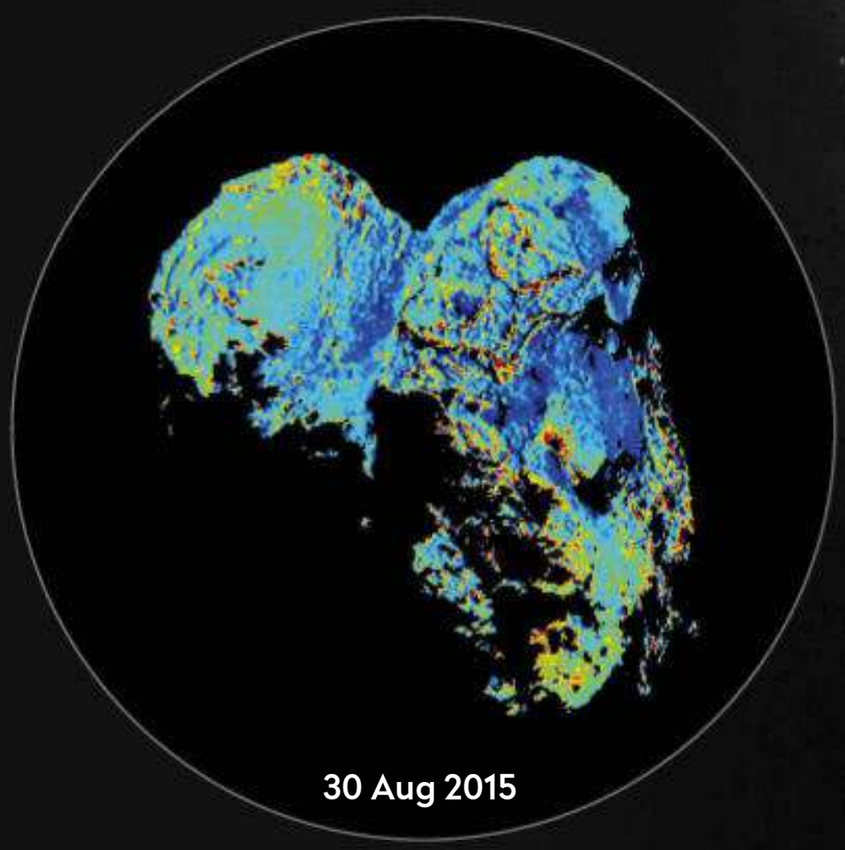
Comet 67P's journey around the Sun

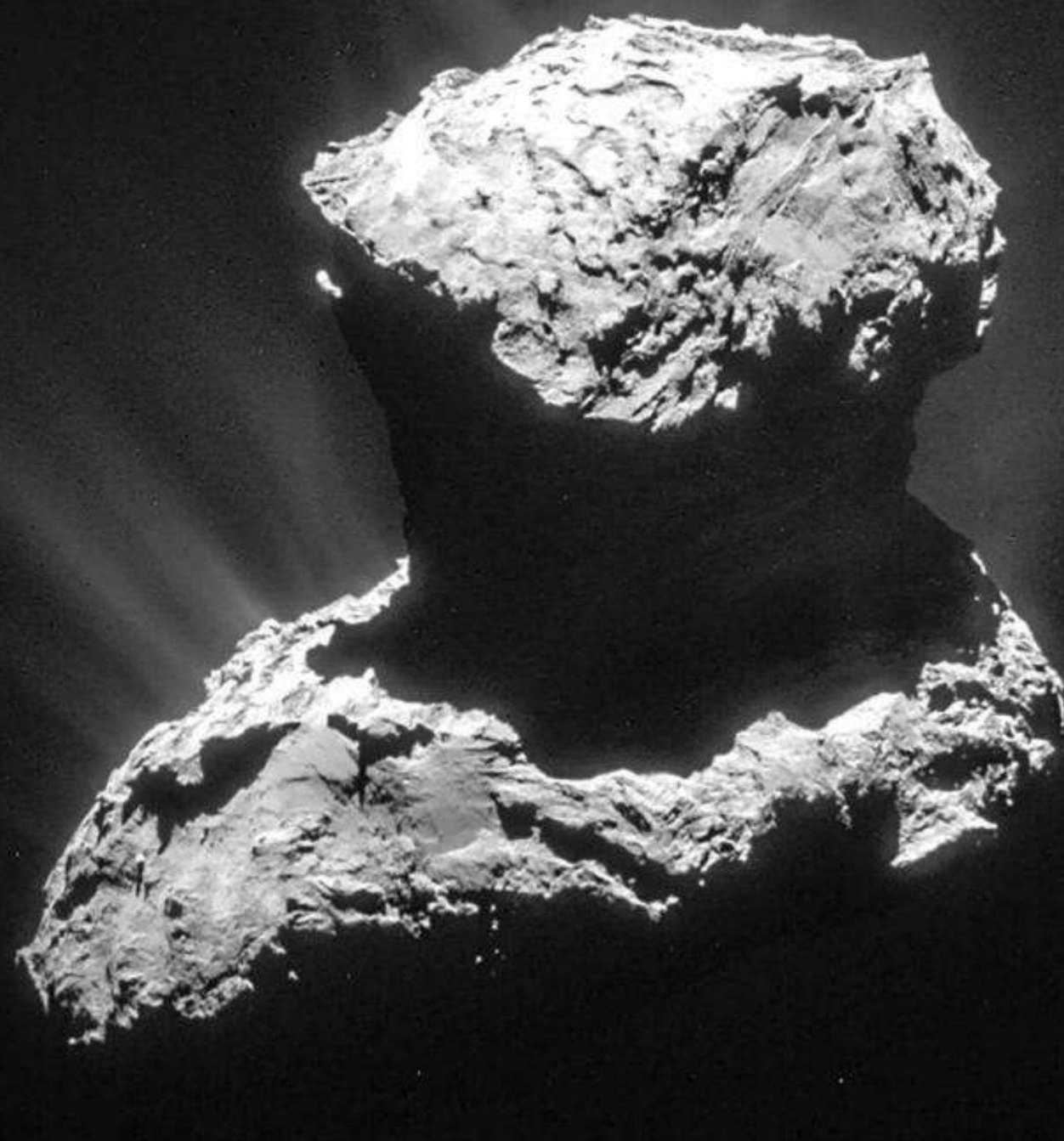
The comet returns to the inner Solar System on 3 November for the first time in 6.5 years

Time to orbit Sun 6.45 years
Aphelion distance 5.7 AU (850 million km)
Perihelion distance 1.2 AU (186 million km)
Discovered 1969
Rotational period approximately 12 hours
Inclination 7°
Place of origin Kuiper Belt
Next perihelion 11 April 2028
Mass 10 trillion kg
Size of nucleus 4.3km x 2.6km x 2.1km









▲ The Sun's heat raised the temperature of 67P when the comet passed close by our star in August 2014. It was captured by Rosetta's OSIRIS infrared camera (see top inset image)

The Sun's heat also increased the rate at which the comet's ice thawed, resulting in a rise in the amount of water vapour released (see main image).

A year later, when 67P was much further from the Sun, OSIRIS recorded the comet's much lower temperature (see lower inset image)

and Neutral Analysis (ROSINA) instrument that made the measurement. "The old idea was that all water on Earth came from comets. Now we know it's probably less than one per cent."

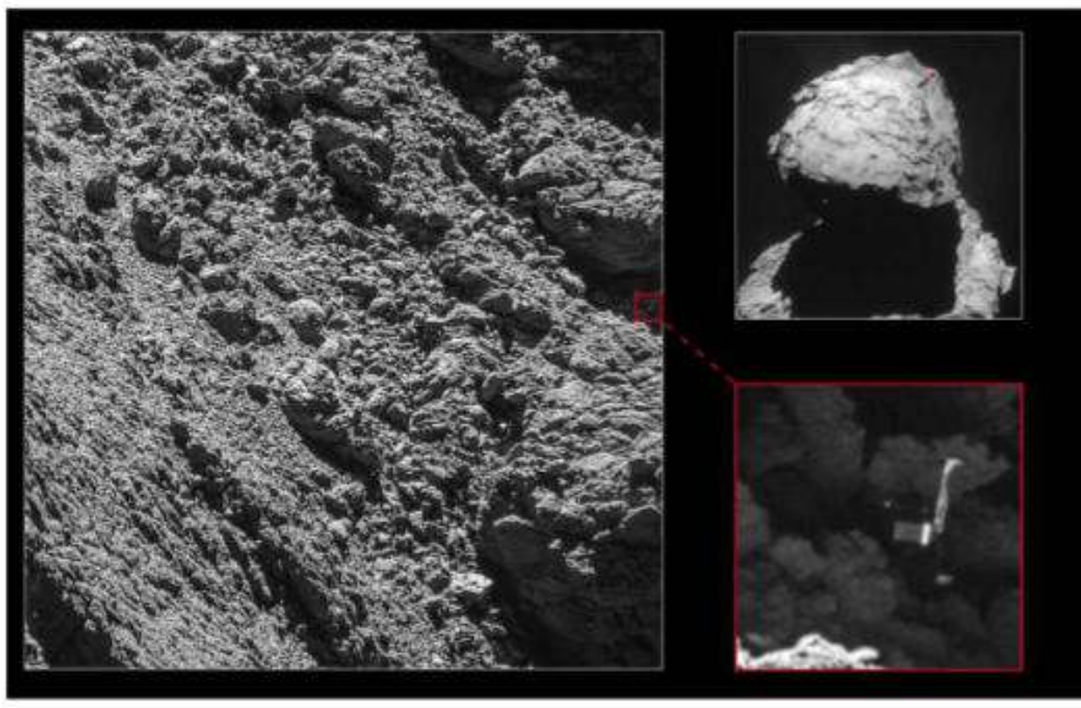
That's not to say comets didn't bring anything important to Earth, as Rosetta revealed they could have been instrumental in transporting the ingredients of life to our planet.

"We found glycine. It's the simplest amino acid, and they're essential for life. To find that in a very cold, lifeless, primitive body was quite a surprise," says Altwegg. "We also found phosphorus, which is another essential ingredient for life. It's probable that most of today's biomass was delivered by comets."

Meanwhile, other instruments focused on the icy nucleus of the comet. The Comet Nucleus Sounding Experiment by Radio wave Transmission (CONSERT), used radar to look inside Rosetta. It found the body wasn't a solid lump of ice, but actually a loosely packed collection of pebbles. Around 75 to 85 per cent of the comet's volume is empty space, suggesting it formed from many small objects bumping together at slow speeds, rather than a high-velocity collision between two large objects.

Hard landing

The surface, however, turned out to be remarkably solid – something the Rosetta team discovered the hard way when they attempted to land Philae. The spacecraft was meant to set down in what appeared



▲ Rosetta images taken on 2 September 2016 finally locate Philae after its unsuccessful landing on 67P

to be a region covered in dust, known as Agilika. On 12 November 2014, the landing team rejoiced as the signal came back saying it had touched down. But their joy was short-lived – it appeared the dust was only a thin layer, covering a hard surface. Several of the mechanisms meant to latch Philae to the surface had broken in transit, so the lander had rebounded off the unexpectedly solid comet.

Philae spent two hours drifting above 67P's surface, eventually coming back down 1km from its intended landing site, in a region named Abydos. It had landed on its side, meaning the drill couldn't deploy correctly and collect an ice sample. To make matters worse, ▸

The future of comet exploration

Comet Interceptor will wait in orbit for a fresh comet to be found

Comet 67P has taught us a lot about the origins of the Solar System, but that's not to stay it's remained unchanged since its creation 4.5 billion years ago. It's passed through perihelion many times, and the cycle of freezing and thawing has changed its composition. If planetary scientists want a comet made of material that's as it was during the formation of the planets, they'll need to find a comet on its first trip to the inner Solar System.

Comet orbits regularly get knocked inwards (67P used to orbit much further out until an interaction with Jupiter in 1959 brought its orbit closer to the Sun). But astronomers get little warning and only find out about these new comets when they're already on their way. So, rather than waiting for one to appear and then hurriedly launching a mission, ESA and the Japanese space agency (JAXA) are working on a joint mission that will wait for a comet in orbit.

Comet Interceptor will launch in 2029, but without a specific target in mind. Instead, it will travel to the second Lagrange point (L2) 1.5 million km behind Earth. And when astronomers spot a suitable comet coming towards us, Comet Interceptor will speed off to investigate. The mission could even become our first 'interstellar' explorer if an interesting object from another solar system passes through ours, such as 'Oumuamua (pictured) or Comet Borisov, which have both visited us in the last few years.

▸ *See 'The Sky Guide – Comets and Asteroids' on page 53, for details of how to observe 67P in November*

ILLUSTRATION

▸ Philae had ended up in the shadow of a cliff, where its solar panels couldn't recharge the battery, so it only functioned for the 64 hours its battery allowed.

Though Philae could only achieve a few of its goals, the lander did manage to get a good look at the surface – in two locations. They showed a highly varied terrain: while Agilkia was a field of smooth dust with wind-blown features carved across the surface, Abydos was a dark and rugged terrain of hard ice and jagged cliffs. The vibrations made by Philae revealed that the hard layer seems to be a universal feature across the comet. It seems the constant cycle of freezing and thawing as the comet nears the Sun before passing back into deep space has created a hard shell surrounding the nucleus's crumbly centre.

An increase in gas

As 67P drew closer to the Sun, Rosetta recorded the comet's temperature rising from –70°C to just below zero and the amount of gas given off dramatically increasing. When the spacecraft first arrived, the comet only gave off around 300g of water a second – about a mugful. By the time it reached perihelion on 13 August 2015 that number had increased 1,000-fold and 67P was throwing out two bathtubs-worth of vapour a second.

This huge amount of material coming from the comet made staying in orbit very difficult for Rosetta. The strong breeze constantly pushed against the 32m^2 surface of the spacecraft's solar panels as it struggled to stay close, while dust also hammered away at its entire structure.

But Rosetta survived, remaining in orbit around the comet for another year. As 67P travelled further into deep space and away from the warming Sun, it slowly returned to a slumber. With the comet dormant once again, Rosetta's job was done. On 30 September 2016, Rosetta began a slow descent towards a smooth spot on the comet's smaller lobe before setting down on the surface in what would be its eternal resting place.

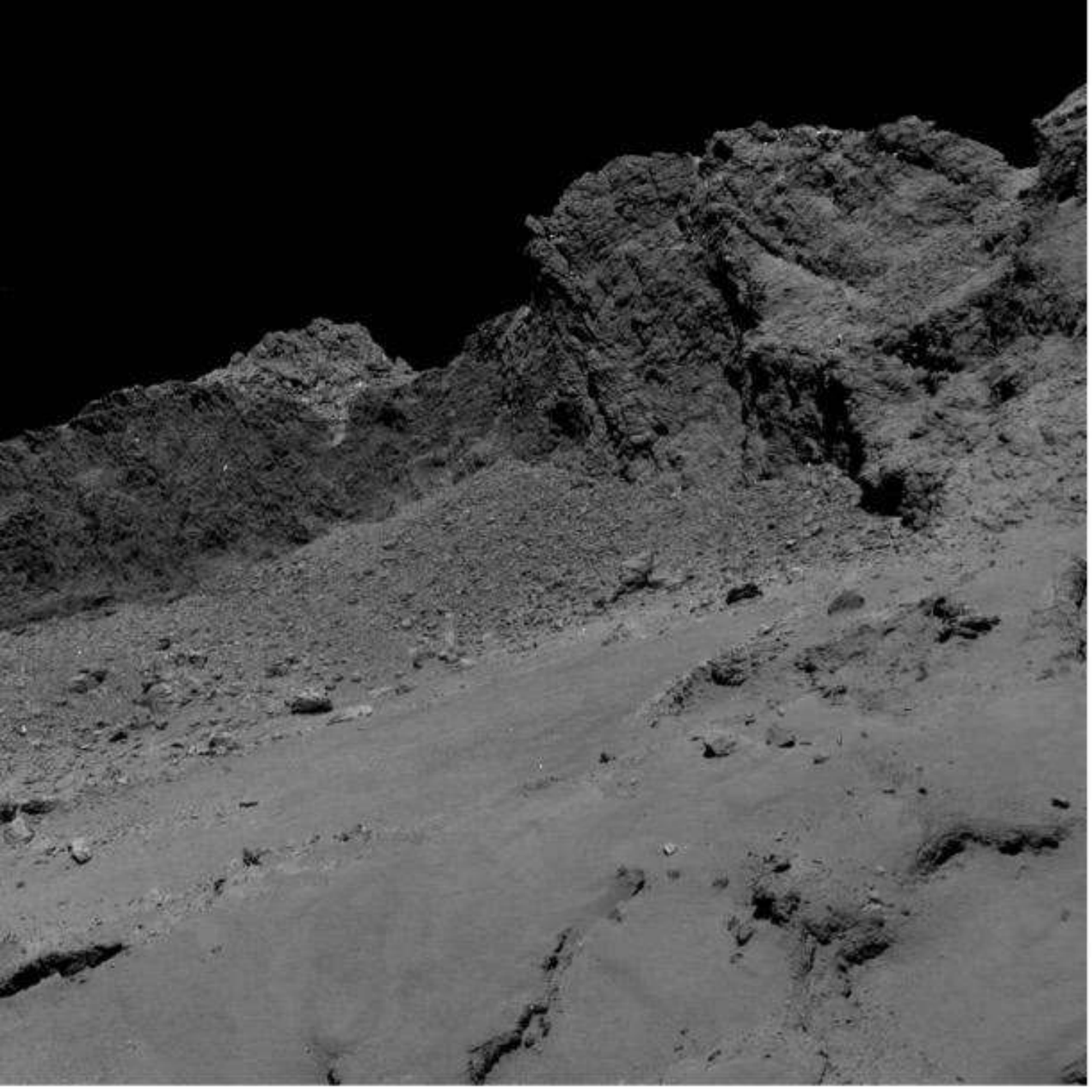
Back on Earth, however, the rest would be considerably shorter. The Rosetta team was now faced with the complex task of consolidating all the data gathered during the spacecraft's long mission, organising the information to make it as useful and easy to interpret as possible.

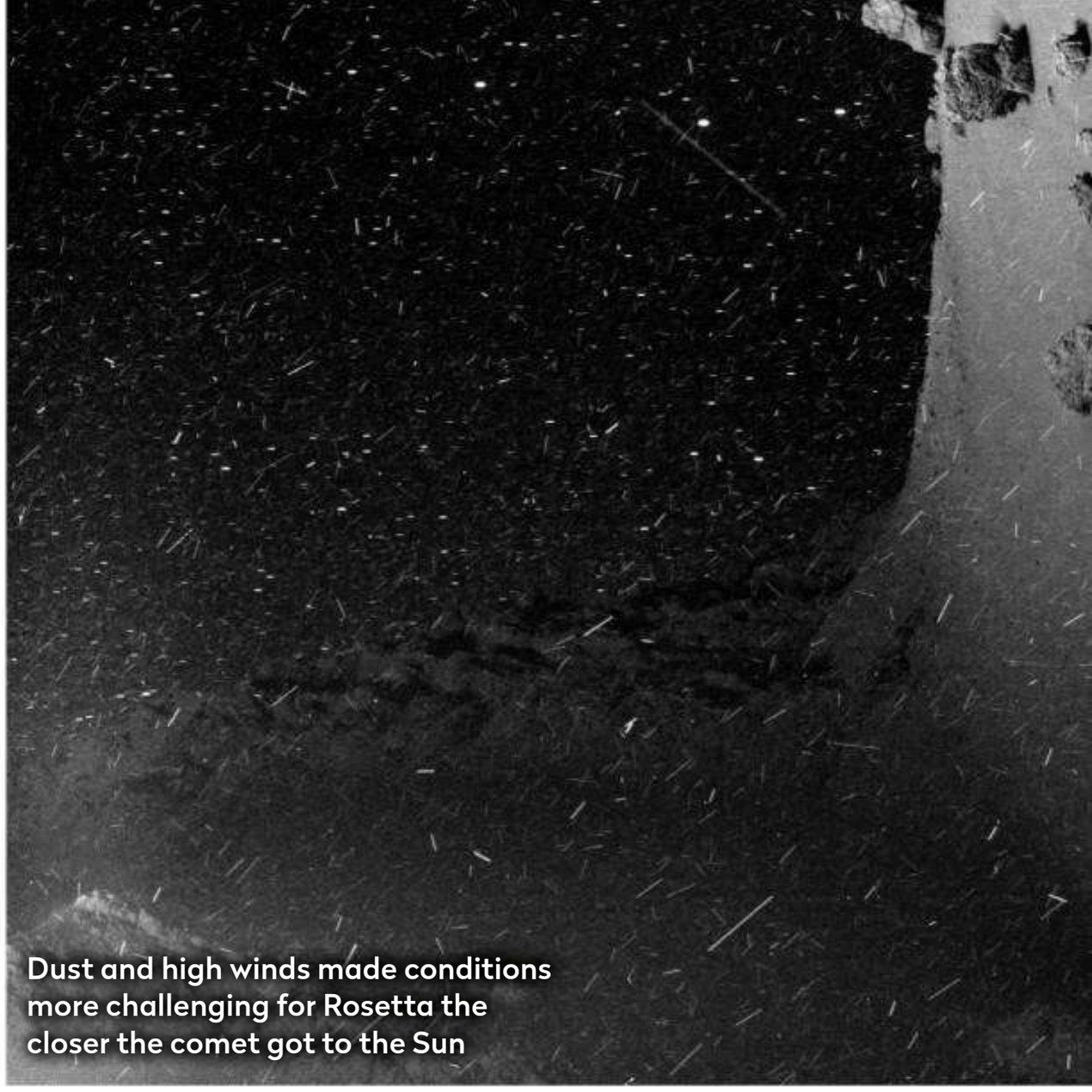
"That consolidation has been critical," says Professor Marina Galand from Imperial College London, one of the scientists working on Rosetta data today. "Now we have this amazing data set available to the whole community where you can look at changes over a season, over heliocentric distance, over latitude."

Importantly, the data set is now properly calibrated. Previously, researchers had only been able to interpret a single experiment at a time, but this step means they can now compare data across all of Rosetta's 11 instruments.

"With one instrument you can learn up to a certain point. When you start to have different instruments

ESA/HUBBLE/NASA/ESO/M. KORNMESSER, ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA X 2, MARK GARLICK/SCIENCE PHOTO LIBRARY/ALAMY





Dust and high winds made conditions more challenging for Rosetta the closer the comet got to the Sun

▲ As Rosetta made its mission-ending descent, the spacecraft's OSIRIS camera captured this image of 67P's surface from an altitude of 16km

ILLUSTRATION

► The cometary aurora found at 67P could give valuable insights into solar wind and space weather

or different types of observation, you can start to fit all the pieces of the puzzle together. That enhances the science return," says Galand.

Further discoveries

This refined data was released to the public in 2019 and researchers have been combing through it ever since, leading to a slew of discoveries. Galand and her team, for instance, looked at far-ultraviolet (UV) emissions in the comet's coma. Though the radiation was detected by Rosetta's UV spectrograph, ALICE, the instrument couldn't pin-point where the emissions came from on its own.

"We used data sets from different instruments. We used ALICE, which looked at the brightness of specific emissions; another instrument looked at energetic electron fluxes. And we measured the density of the gas from the infrared," says Galand.

With all this information, the team was able to confirm that the emissions came from a dancing aurora, encompassing the comet as it passed around the Sun. While this ultraviolet emission is invisible to the human eye, there were hints of the 630nm emission produced by oxygen, which is responsible for the red tones seen in Earth's aurora. Fortunately, the comet's return to perihelion offers the perfect chance to have another look for this emission.

"We couldn't observe the comet before at perihelion, because it was on the other side of the Sun to Earth," says Galand. But that's not the case this time and many teams are planning on observing the comet this November. "That will give context because we've seen in close and now we can see from a different perspective," she says.

Herein lies the real legacy of the Rosetta mission. Before the orbital mission, no one would have thought to look for aurora around a comet, but now they know it's there, astronomers can use ground-based telescopes to look for it around 67P – or any other comet that comes by. And this is just one study, which had looked at the data for just a few months. More revelations are waiting to be made as astronomers dig further into the data.

"Today, people are still publishing data from the comet flyby mission Giotto, which was just a few hours of data acquisition in 1986," says Galand. "Here we have two years of data and we've not yet looked at its whole wealth."

So while the Rosetta mission may be over, but its scientific legacy has only just begun to emerge.

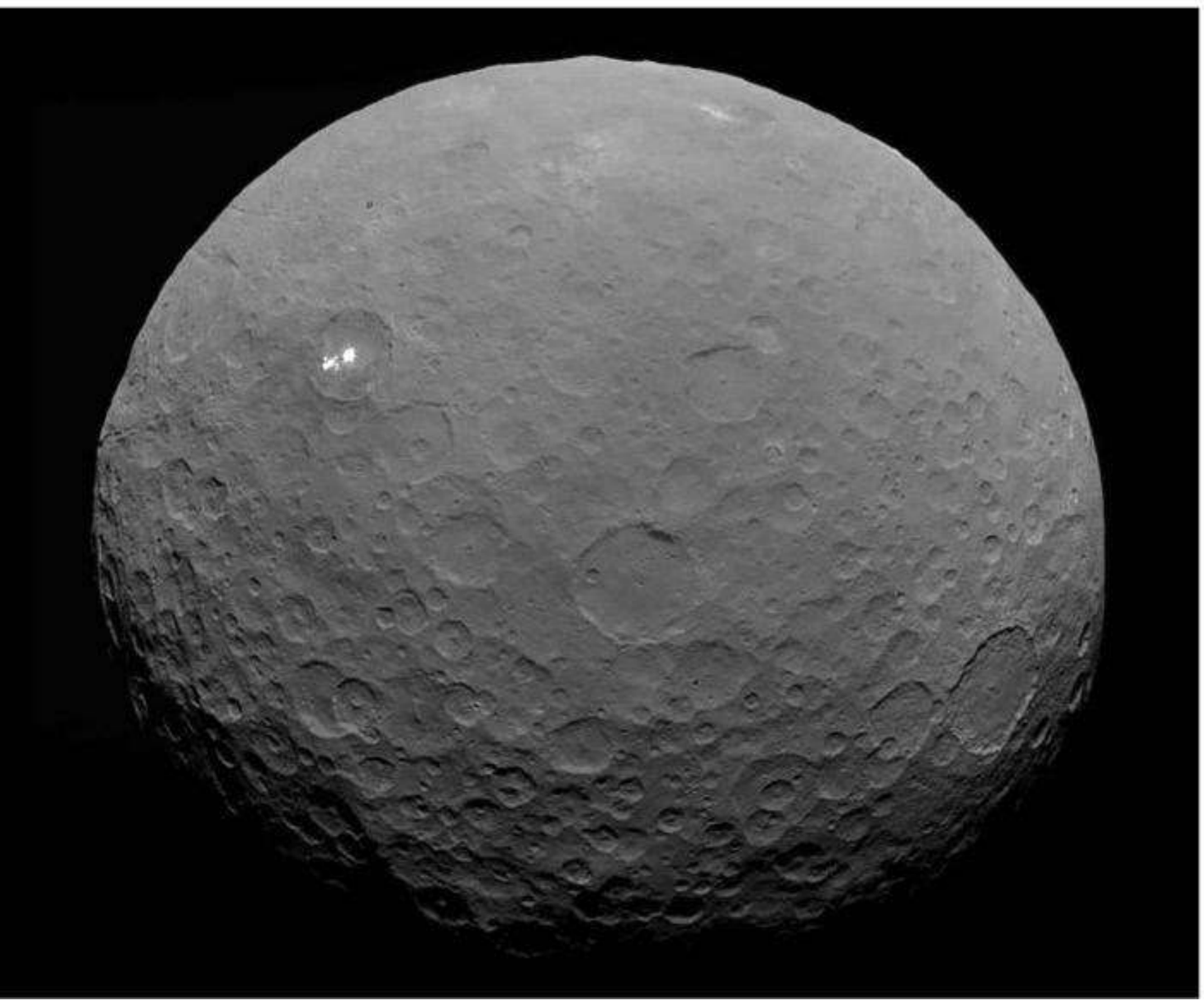
Dr Ezzy Pearson is *BBC Sky at Night Magazine*'s news editor. She has a PhD in extragalactic astronomy

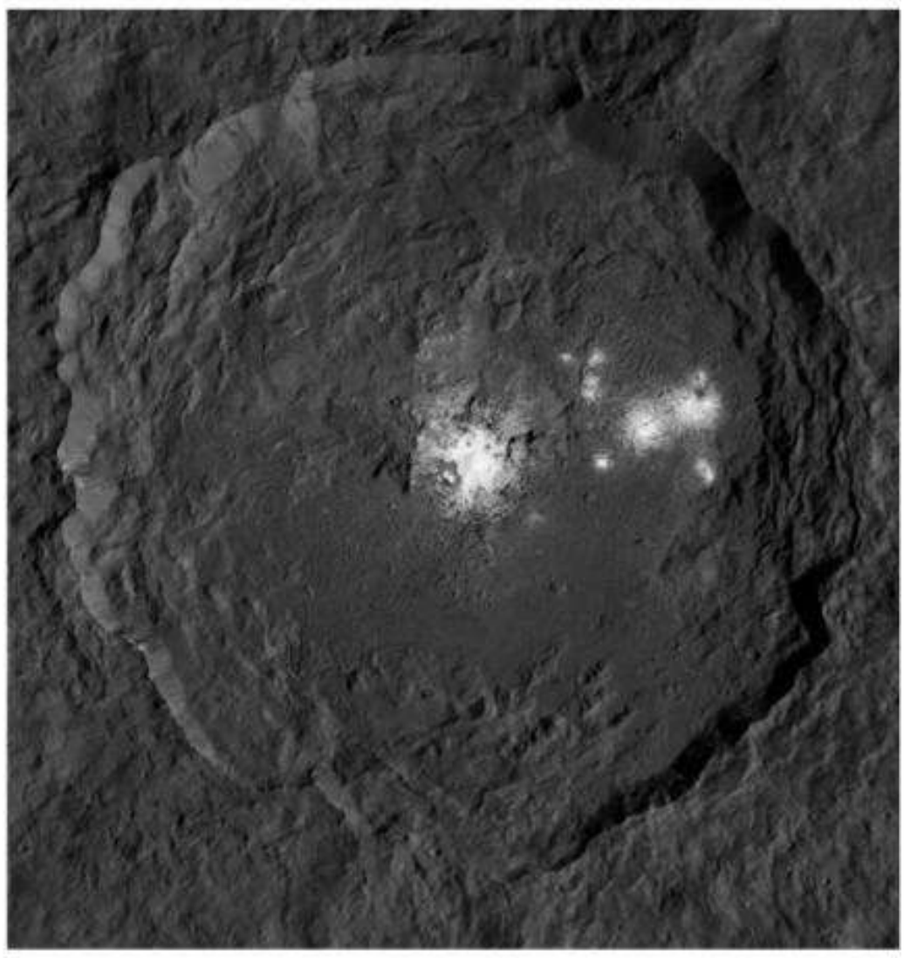
The fundamentals of astronomy for beginners

EXPLAINER

Ceres, the planet that never was

From ‘comet’ to ‘planet’, then ‘asteroid’ to ‘dwarf planet’, **Jane Green** looks at the changing classifications of Ceres, which reaches opposition this month





Ask anyone to name a dwarf planet and the answer is likely to be Pluto. Since its discovery in 1930, Pluto had been classed as a classical planet and it wasn’t ‘demoted’ to its dwarf status until 2006. But it wasn’t the first planet to be reclassified. That honour belongs to the lesser-known dwarf planet Ceres, which happens to reach opposition – when it will be on the opposite side of Earth to the Sun – on 27 November. So, it’s a fitting time to shine more than sunlight on this 940km-wide world which has proven to pack a pretty good cryogenic punch.

Ceres is named after the Roman goddess of corn and harvests (she also gives us the word cereal). It was discovered on New Year’s Day 1801, by Catholic priest Giuseppe Piazzi at the Palermo Astronomical Observatory, Sicily. Piazzi’s discovery was the result of a methodical search using the now discredited

▲ Above: an image of Ceres taken from a distance of just 13,600km by NASA’s Dawn mission in May 2015 reveals mysterious bright patches on the dwarf planet

Above right: One of the dwarf planet’s brightest areas was spotted in the crater Occator – leading to speculation of an underground salty reservoir

Titius-Bode Law, named in 1766 after German astronomer Johann Daniel Titius and popularised from 1772 by his countryman Johann Elert Bode. This law formulaically predicted a pattern in the size of orbits of the planets and mathematically suggested that another planet existed in the gap between the orbits of Mars and Jupiter.

When Piazzi discovered this ‘missing planet’ he thought the new ‘moving star’ was a comet. He observed its ‘slow’ and ‘rather uniform’ movement a further 24 times before becoming convinced it was not one. He announced his sighting on 24 January 1801. At the time, it was the only known object between Mars and Jupiter yet it soon became lost in the Sun’s glare and impossible to see. Nevertheless, its orbit was mathematically predicted by the 24-year-old German mathematician Carl Friedrich Gauss, one of the ‘Celestial Police’ – an elite group of planet-hunting astronomers who were also making observations of Ceres. However, they kept discovering other objects in similar orbits, and slowly the realisation dawned that they were dealing with an entirely new class of bodies.

In 1802, with the discovery of Pallas, German-born

NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA X 2, MELETIOS
VERRAS/ISTOCK/GETTY IMAGES, CHART BY PETE LAWRENCE

HOW TO OBSERVE CERES AT OPPOSITION

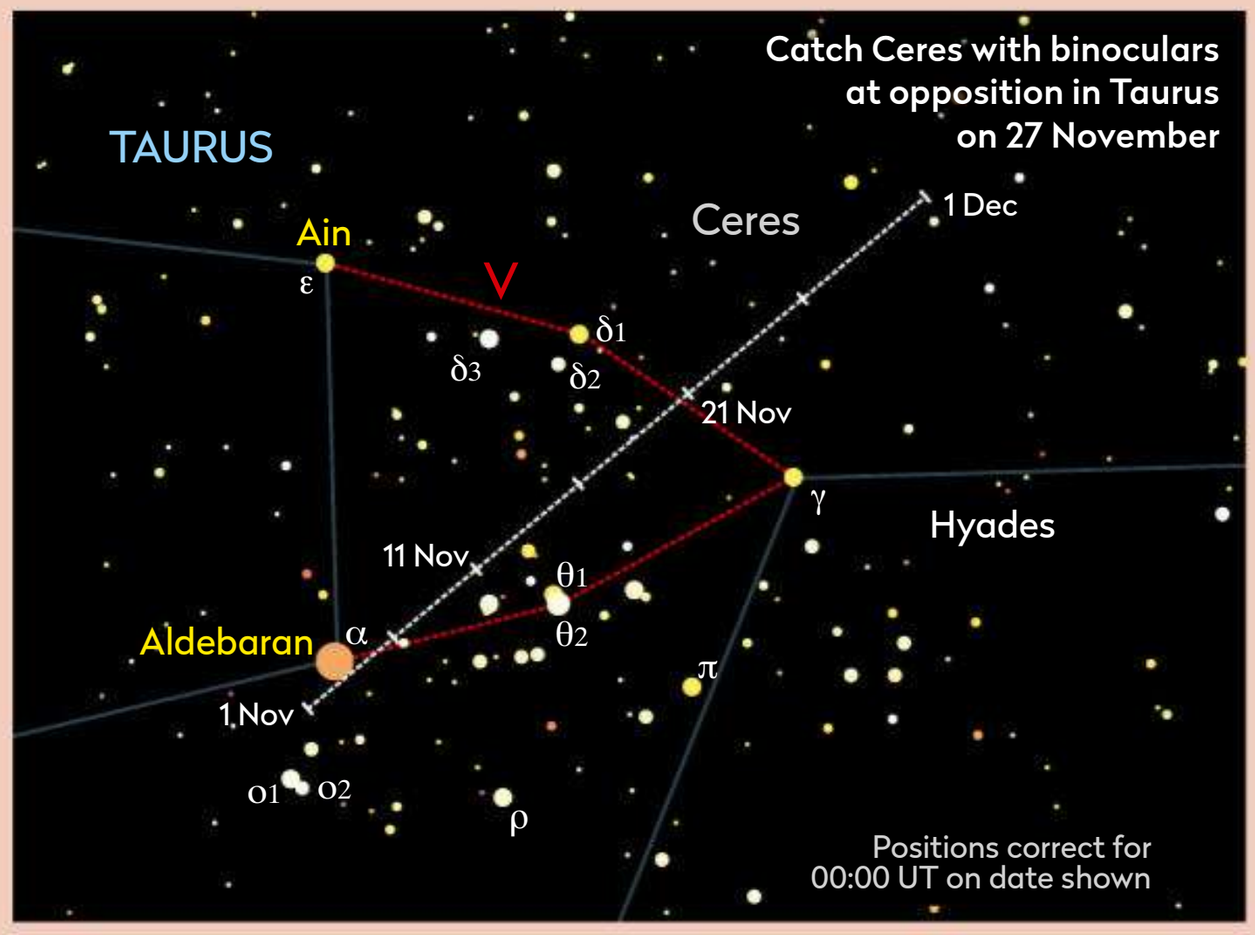
Enjoy the dwarf planet as it appears at its brightest in the night sky

Ceres reaches opposition – a position in space on the opposite side of Earth to the Sun – in the constellation of Taurus, the Bull, on 27 November. Catch it at its closest approach to Earth when it's visible at its highest point in the sky around midnight. Its star-like point of light will shine at mag. +7.2, within the range of 10x50 binoculars.

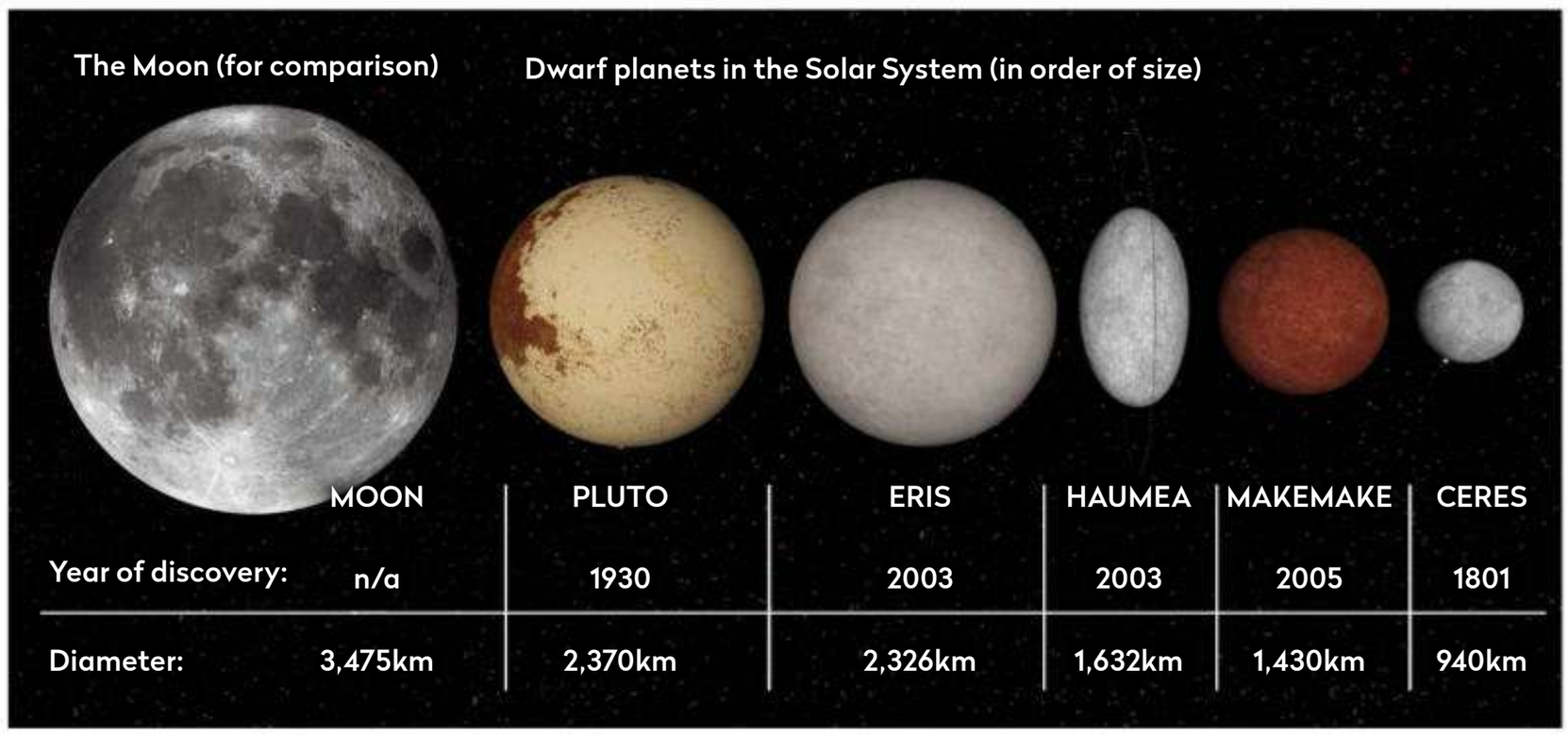
A binocular object throughout the month, the best times to view Ceres will be from midnight UT on 1 November, 23:00 UT on the 15th and 22:00 UT on 30 November.

Between 1/2 and 3/4 November the dwarf planet passes just south of the red giant star Aldebaran (alpha α Tauri) with the pair closest on the night of 2/3, separated by only 7 arcminutes.

Thereafter, Ceres crosses the Hyades open cluster, before exiting mid-month towards the constellation of Aries, the Ram.



British astronomer William Herschel dubbed this new class of bodies 'asteroids'. In 1851 Ceres was reclassified as an asteroid and designated 1 Ceres, since it had been the first to be discovered. We know now it is the largest of many planetary leftovers forming the asteroid belt between Mars and Jupiter, and accounts for a third of the belt's mass.



▲ A comparison of sizes between each of the five confirmed dwarf planets in our Solar System and the Moon

Name changes

There Ceres remained, classified as an asteroid, until August 2006, when the International Astronomical Union (IAU) – the body responsible for astronomical nomenclature and classification – determined the three criteria necessary for an object to be defined as a planet. These are: to have enough mass to be nearly rounded by its own gravity – known as hydrostatic equilibrium; to be in orbit around a star, not be a star itself nor a satellite of a planet; and, crucially, to have cleared the neighbourhood around its orbit. Pluto failed to meet these new criteria and was demoted from being a classical planet to a dwarf planet – amid some controversy. Ceres, however, was large enough to be rounded by its own gravity and was, therefore, officially upgraded from asteroid to dwarf planet – the only one inside Neptune's orbit. Vesta, once second to Ceres, took on the mantle of the largest asteroid.

Ceres has proven to be an exciting object to explore. NASA's Dawn spacecraft – launched 2007 – arrived at Ceres in 2015, making it the first dwarf planet visited by a spacecraft. As it flew over its cratered surface, Dawn discovered 130 mysterious 'bright spots', the brightest nestling within the recently formed 92km-wide Occator crater. Variations in the gravitational field of Ceres led astronomers to believe they were seeing signs of an underground reservoir of salty water, possibly stretching for hundreds of kilometres and reaching depths of some 40km.

It's speculated that many millions of years ago a space rock impacted the area, and elsewhere, puncturing the icy crust of Ceres to release briny fluid from below. The salty crust then froze over, sealing beneath it a chamber of meltwater and a cocktail of chemicals. This later erupted – perhaps as recently as two million years ago – in the form of an icy volcano disgorging its frozen contents to splatter and dazzle the shadowy world. Indeed, before Dawn, ESA's Herschel Space Telescope had detected water vapour in this area. Ceres could be composed of as much as 25 per cent water – more than Earth – so who knows what exciting revelations future missions will reveal? Until they do, let's enjoy this month's optimum views!

Jane Green is an astronomy writer and author of the Haynes Astronomy Manual

ADVERTISEMENT FEATURE

EXPLORE SOUTH AFRICAN SKIES

Join **Professor John Zarnecki**, the world-renowned space scientist, on a southern hemisphere journey of discovery – part of Saga's collection of expert-led trips

Meet a Cultural Odyssey expert

Professor John Zarnecki accompanies this tour. Emeritus Professor at the Open University, John is a distinguished space scientist who has contributed to high-profile missions such as the Giotto probe that visited Halley's Comet, and the Hubble Telescope.

The largest single optical telescope in the southern hemisphere lies high in the Great Karoo, South Africa. With an 11m-wide mirror, the South African Large Telescope (SALT) at the Southern Africa Observatory is powerful enough to detect a candle on the moon, and stars one billion times dimmer than the faintest visible to the unaided eye.

Dark skies and a long tradition of astronomical research – the South African Astronomical Observatory in Cape Town celebrated its 200th anniversary in 2020 – make the country a thrilling destination for astrotourism. But how can you get a real insight into the southern hemisphere skies, and be sure that you'll see the rest of what South Africa offers as well? The answer is to be found on a new trip from the award-winning tour operator Saga, accompanied by one of the world's leading space scientists.

SOUTH AFRICA BY NIGHT AND DAY

Saga's Astronomy in South Africa tour is part of a new collection of Cultural Odyssey Tours, all of them combining spectacular locations with deep insight from specialist experts. Devised in partnership with the UK's Royal Astronomical Society, the trip explores South Africa in the company of Professor John Zarnecki, a space scientist and key player in the ambitious Cassini-Huygens mission to Saturn. It begins with a lecture and tour of the Society's London HQ before travelling to Cape Town and then on to Sutherland and Prince Albert in the Karoo wilderness, with a daytime visit to the SALT.

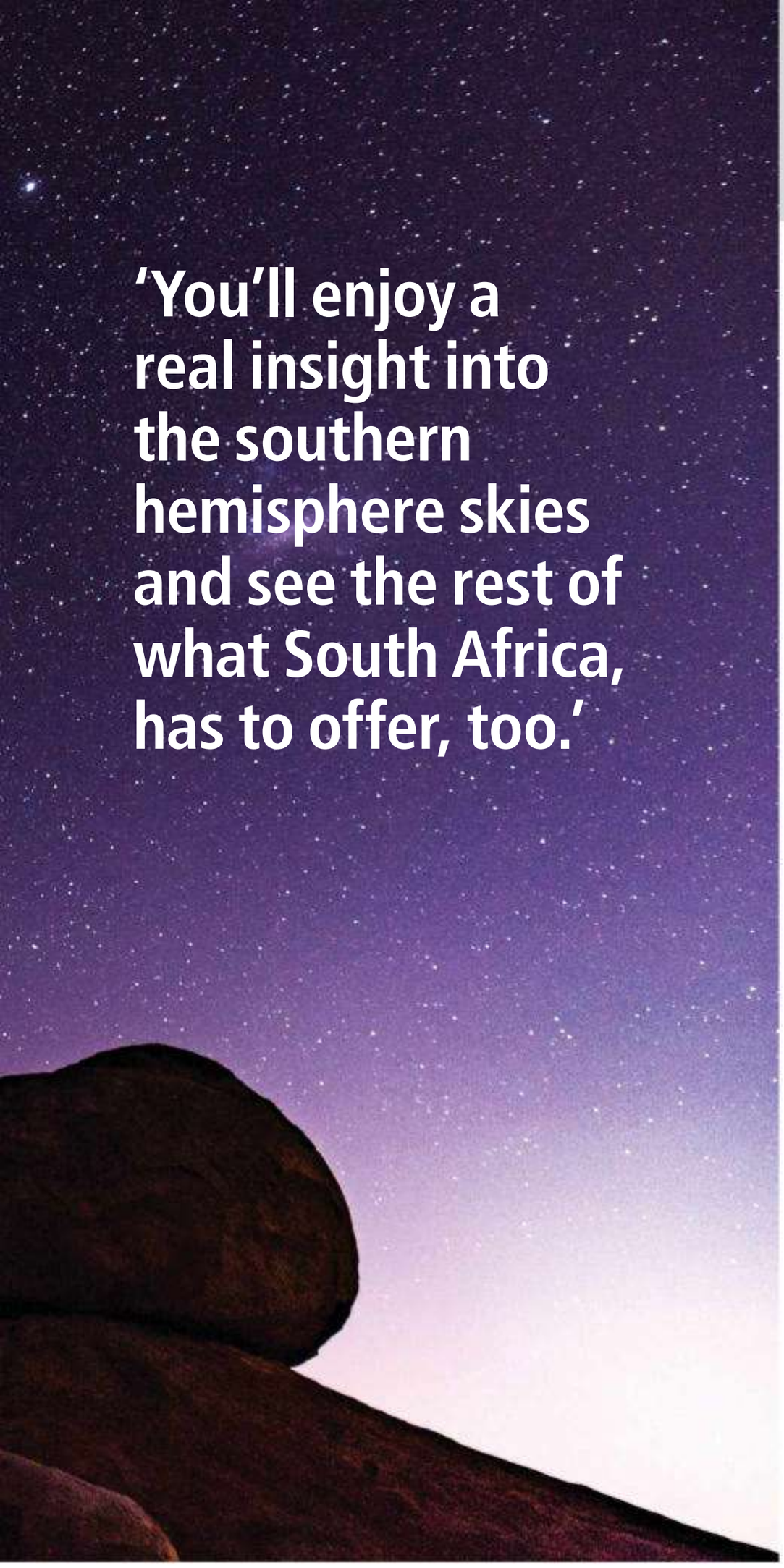
BEYOND ASTRONOMY

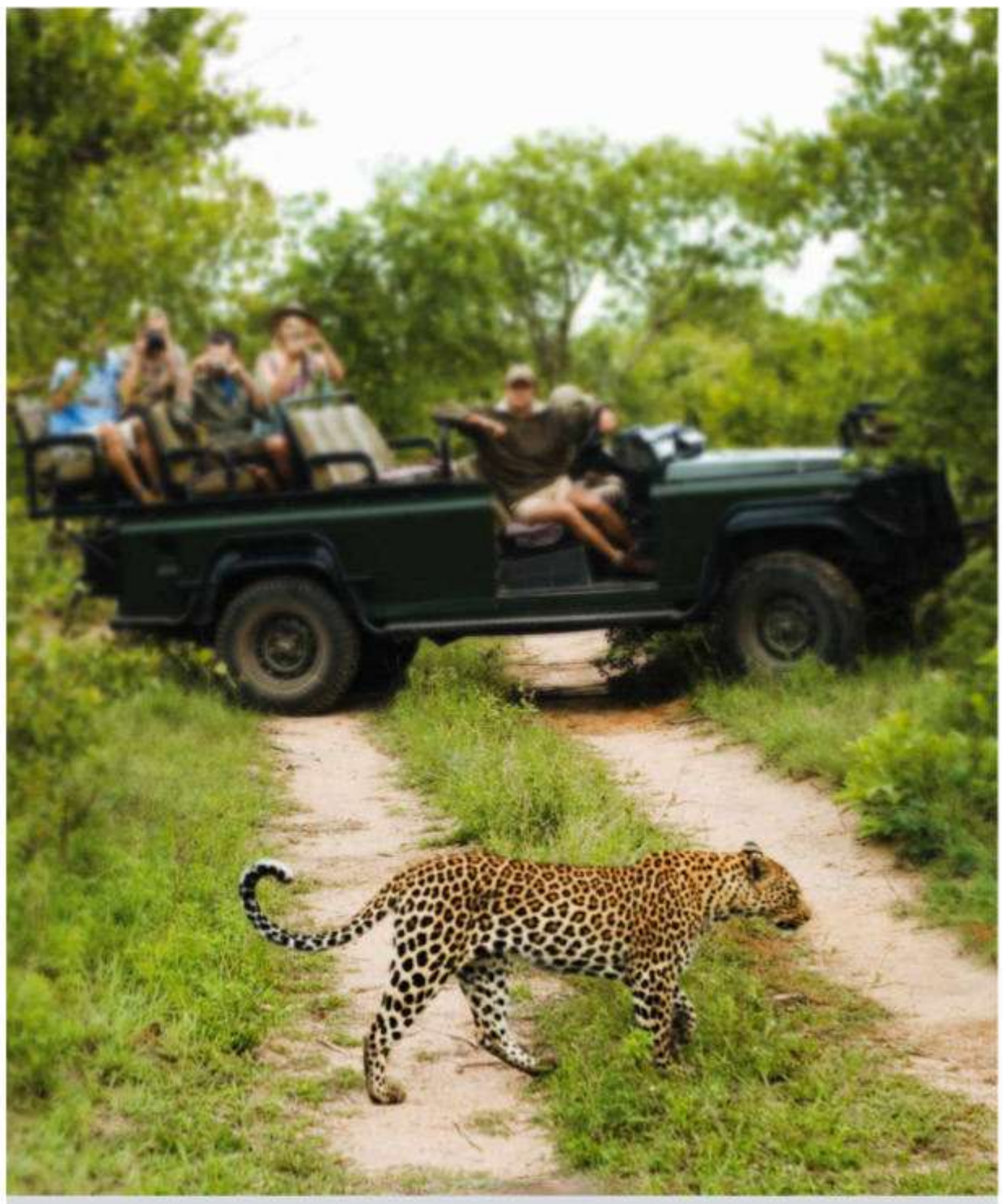
There's plenty of time to sample the best of South Africa below sky level too, with time in the Franschoek winelands and in a tented safari lodge in the Kruger National Park, with a chance to view the Big Five.

As with all the tours in this collection, the holiday includes some exceptional places to stay and the chance to sample high-end local gastronomy – so it's not just about feeding the mind.

If you love the idea of learning about other places and cultures, there are plenty of other trips in the collection to tantalise you, too. They take you to

PHOTOS: ALAMY; WIKIMEDIA (LENGAU); ANDREAS DR ESS; SAGA





Whether it’s stargazing with the naked eye in the wilderness, or with the aid of a telescope, you’ll view the sky’s wonders alongside expert astronomers when you’re on an Astronomy in South Africa Cultural Odyssey Tour. But, as fascinating as they are, this tour is not only about the stars: along the way you’ll also visit historic towns, sample wine in Franschoek (the food capital of South Africa) and experience the wildlife in Kruger National Park, too.

stunning destinations and provide a deep dive into history, art, literature, ballet and music. All are accompanied by experts in their field – academics, authors and specialist guides.

Perhaps you would enjoy a tour of the Hermitage in St Petersburg with an eminent art historian? The chance to roam Shakespeare’s Italy with an actress who specialises in the First Folio? Maybe you’d prefer to soak up the spirit of Andalucia with a flamenco scholar, or travel with an award-winning writer into Ottoman and Byzantine Istanbul.

These specialists have been chosen for their expertise and their passion – there will be no dusty lectures here. On some tours, they’ll accompany you for exclusive behind-the-scenes visits and private performances, giving a fascinating perspective on new discoveries as well as cities you may already love.

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As you’d expect from a company with 70 years’ experience organising award-winning holidays for the over 50s, Saga takes care of you every step of the way. Each trip includes the services of a tour manager or cruise host. Getting to the airport is stress-free, thanks to a chauffeured VIP car service. And the trip prices include flights, transfers and porterage, as well as extras such as travel insurance to cover Covid cancellation. These ABTA- and ATOL-protected trips offer peace of mind and the knowledge that Saga has thought of everything – so you don’t have to. All you need to do is pack your suitcase and bring your curiosity with you for the journey of a lifetime.

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BBC Sky at Night readers will receive an exclusive 5% discount on all Saga Cultural Odyssey Tours by quoting ‘BS5CT’ when booking. To find out more, visit the Escorted Tours section at saga.co.uk/night-sky

SAGA

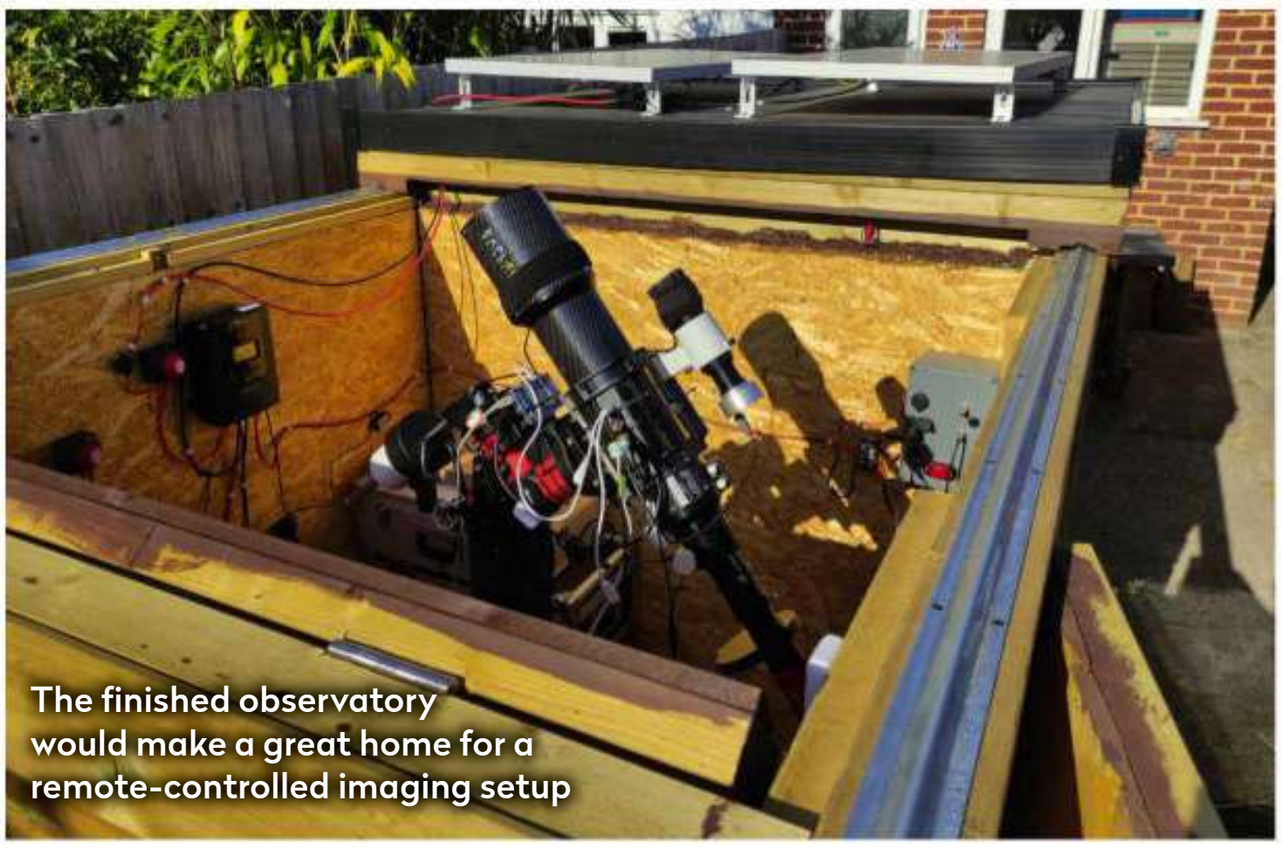
Practical astronomy projects for every level of expertise

DIY ASTRONOMY

Build a roll-off roof garden observatory

PART 1 OF 3

In part 1 we look at how to locate the observatory and build the floors and walls



The finished observatory would make a great home for a remote-controlled imaging setup

Setting up a telescope and a mount for an evening's observing can take over an hour – more if you're imaging and add a camera in the mix – and nearly as long to put it all away again. However, if you have even the most basic observatory, setting up can take less than five minutes; as the cliché goes, it's a game changer.

In this series of three articles, we'll look at creating a roll-off roof (ROR) observatory that has minimal impact in a small garden. We'll cover the basic structure, the design and installation of solar panels (photovoltaics or PV), and also how to add a remote control system to it for an imaging setup.

Let's begin with the structure itself. A roll-off roof is easier to construct than a conventional dome, and the roof is more suitable for solar panels. A small observatory is classed as 'permitted development', but there are exceptions, so you should contact your local planning authority if you are in any doubt.

The movement of a telescope on an equatorial mount describes an (imaginary) sphere, so this will determine the minimum internal dimensions of the building. A simple way to work out the radius is to use a piece of string to measure the distance from the intersection of the right ascension (RA) and declination (dec.) axes to the most distant point on the scope (usually the front of the objective lens or back of the eyepiece/camera). If your observatory needs to fit you in as well, make ample allowance for that.

Steve Tonkin is a binocular observer who takes part in projects with The Astronomical Unit

Making foundations

Unless you are competent with groundwork, you may need a builder, and they will need a plan and elevation drawings of the work. In our design, the walls and roof are supported by the four corner posts, so the footings for these must be substantial. The stem walls support only the floor's weight, so shallow footings are fine here.

We had a sturdy tripod, so our floor design included three concrete pads for its feet, but you may prefer to have a central pier set on a pad. You must isolate your pads from the floor so that any vibration in the rest of the observatory is not transmitted to the scope.

It's a good idea to incorporate security at the design stage, including an alarm and a padlock: we used security bolts and stud hinges on the door.

A bugbear of many observatories is condensation. You can incorporate passive control of this with a combination of insulation and ventilation. The insulation reduces large, rapid temperature changes and ventilation reduces the likelihood of trapping warm air that will condense as it cools.

Next month, we'll show you how we overcame a disadvantage of ROR observatories, which is the extra footprint needed to support the roof-runners.

MORE **ONLINE**

Download a plan and measurements for your roll-off roof observatory build. See page 5 for instructions

What you'll need

- Tools include a circular saw (follow all the safety precautions and always wear appropriate protective equipment); and a staple gun for securing the vapour membrane.
- A portable workbench and a trestle; a green laser level; a tarpaulin to protect the unfinished observatory from the elements.
- Materials include a damp-proof membrane; OSB3 orientated standard board (11mm and 18mm); 25mm insulation board; vapour barrier; shiplap cladding; 95mm x 45mm kiln-dried timber; 25mm x 50mm battens; security hinges and bolts; plus screws and nails.

ALL PICTURES: STEVE TONKIN

Step by step

Step 1

Once you've chosen your observatory's location, the next step is to calculate the internal size of the building. We verified our calculations by making a framework of canes and ensured that no part of the telescope moved outside the framework (except at the top).

Step 2

We engaged a local builder to do the groundwork and install the footings for the posts that support the main structure, as well as the concrete block pads on which our tripod would stand, and the stem walls of two courses of engineering bricks that support the floor.

Step 3

We damp-proofed the concrete pads and covered the ground with weed-block fabric on which we laid polystyrene insulation board. The floor is 18mm OSB3 board, supported on 95mm x 45mm timber joists, resting on damp-proof membrane on the stem walls.

Step 4

The inside walls are 11mm OSB3 board, which we fixed to the corner posts with wooden blocks and reinforced in the middle with vertical battens. Angle brackets are useful for securing the battens to the floor. (The batten at the top of the wall is temporary).

Step 5

Insulation will help control condensation inside the observatory. The walls have a layer of 25mm polystyrene insulation board, which is held in place by friction, then there's an air-space between this and a sheet of vapour barrier that we stapled to the posts.

Step 6

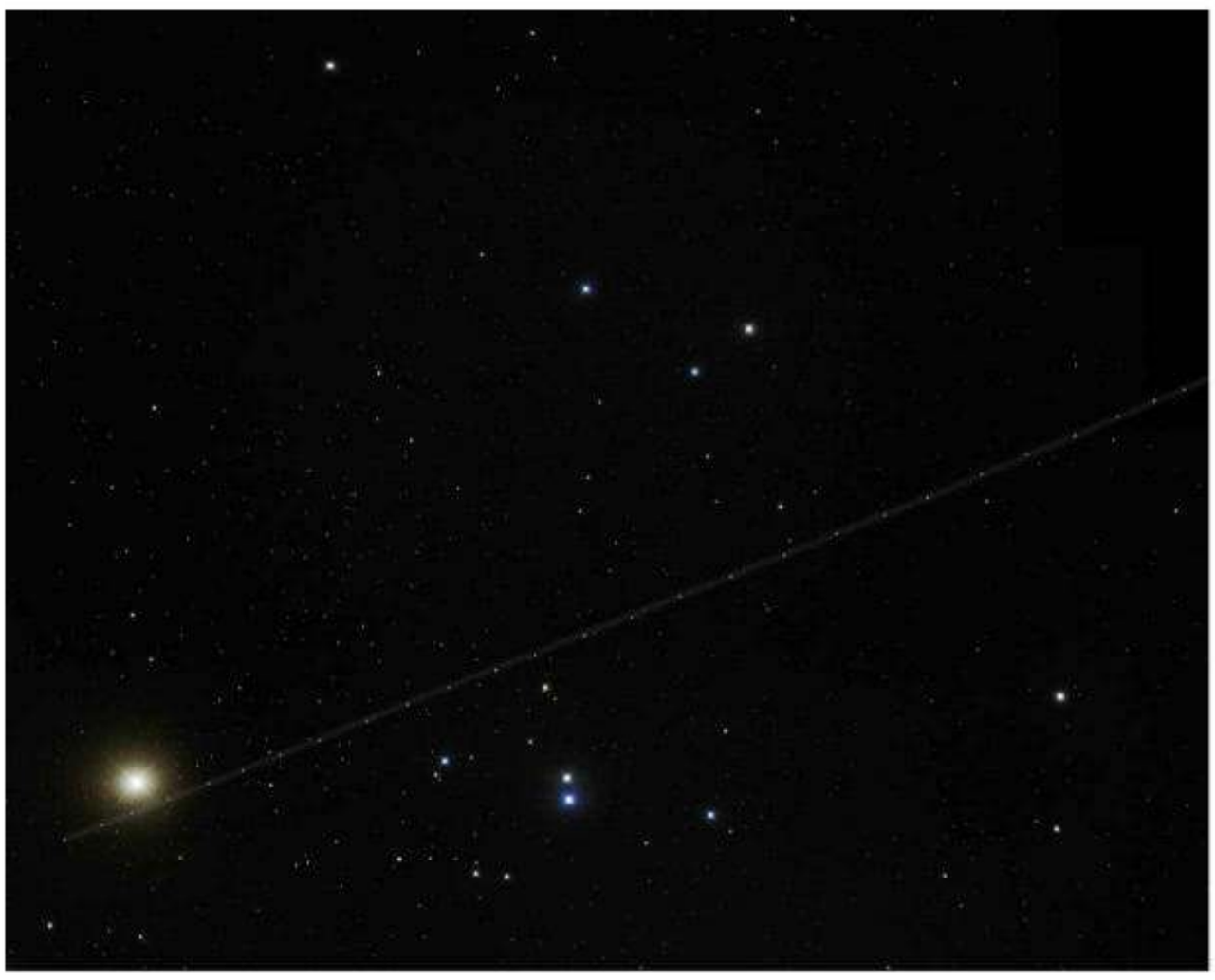
The outer layer of the wall is pressure-treated shiplap cladding, secured over the vapour barrier layer. Any cut ends of timber will no longer be water resistant, so use a wood treatment on them in accordance with the manufacturer's instructions.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Imaging Ceres in the Hyades

Track the progress of the dwarf planet as it passes across the open cluster in Taurus



Dwarf planet Ceres reaches opposition this month and by chance it does so while tracking across the Hyades open cluster in Taurus, the Bull. Shining at seventh magnitude, Ceres isn't difficult to see, but normally you do need a few star-hopping skills to locate it. Within the Hyades, this isn't the case – assuming you can find the Hyades of course! To find Ceres, follow the line of Orion's Belt northwest to arrive at orange Aldebaran (Alpha (α) Tauri). The Hyades is the sideways V-shaped pattern next to Aldebaran, which is visible to the naked eye and easy to find from the bright star.

▲ Create an image that captures the progress of Ceres throughout November, as it passes close to Aldebaran (bottom left) and across the Hyades open cluster

On the trail of Ceres

Aldebaran marks the start point for Ceres's track across the cluster, the dwarf planet being located just to the east-southeast of the star at the start of the month. It then moves to pass 10 arcminutes south of Aldebaran on the morning of 3 November. Its subsequent passage takes Ceres through the main V-shape of the Hyades, before eventually leaving the pattern on 20 November. On 30 November, Ceres sits 2.3° northwest of Gamma (γ) Tauri, the star that marks the bottom point of the 'V'.

If you have equipment that can photograph at least down to mag. +8.0, and as long as you can image the main V-shape of the cluster in a single go, you should be able to record Ceres. Your setup doesn't need to be complex and recording stars down to mag. +8.0 with modern cameras isn't difficult.

A tracking mount will make the job easier, but it's not essential. If you're using a static mounted camera (on a tripod, for example) use the 500 Rule to work out the longest exposure you can make: it's 500 divided by the focal length in millimetres of the lens you're using. This assumes you're using a full-format 35mm sensor. If you're using a camera with a slightly smaller APS-C-type sensor, you'll need to multiply your lens's focal length by the correction factor, which is typically 1.6x.

If you use a lens with a focal length of 500mm, the longest exposure you can take without stars starting to trail will be: *500 ÷ 500 = 1 second*. If you're using a 50mm lens, you've got longer: *500 ÷ 50 = 10 seconds*. If you're using a 110mm lens attached to an APS-C camera with a 1.6x frame correction value, your longest exposure time is: *500 ÷ (1.6 x 110) = 2.8 seconds*.

Using a static, non-tracking, mount all you need to do is adjust your camera and lens settings to record stars down to at least mag. +8.0, in exposures shorter than that given by the 500 Rule. Achieve this, and dwarf planet Ceres will be perfectly placed for you to photograph throughout November.

▸ For more about Ceres, see 'Explainer' on page 72

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Recommended equipment: DSLR or equivalent, a lens, polar-aligned tracking mount (optional)

✉ Send your images to: gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

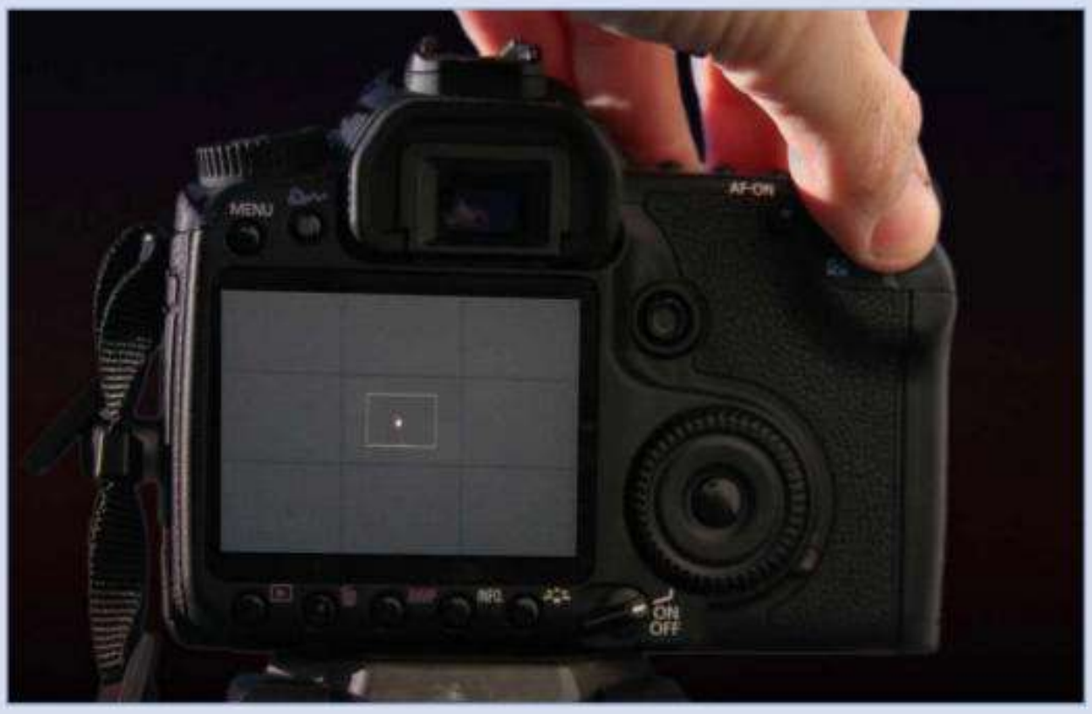
Step by step

STEP 1

A Hyades photo looks best if the cluster can 'breathe', so frame it with plenty of sky. A field of view measuring 12 x 8° allows the full month's track with a decent sky margin to be recorded. A 170mm or shorter focal-length lens on a 35mm sensor achieves this. For APS-C sensors, use 110mm or shorter for a similar result.

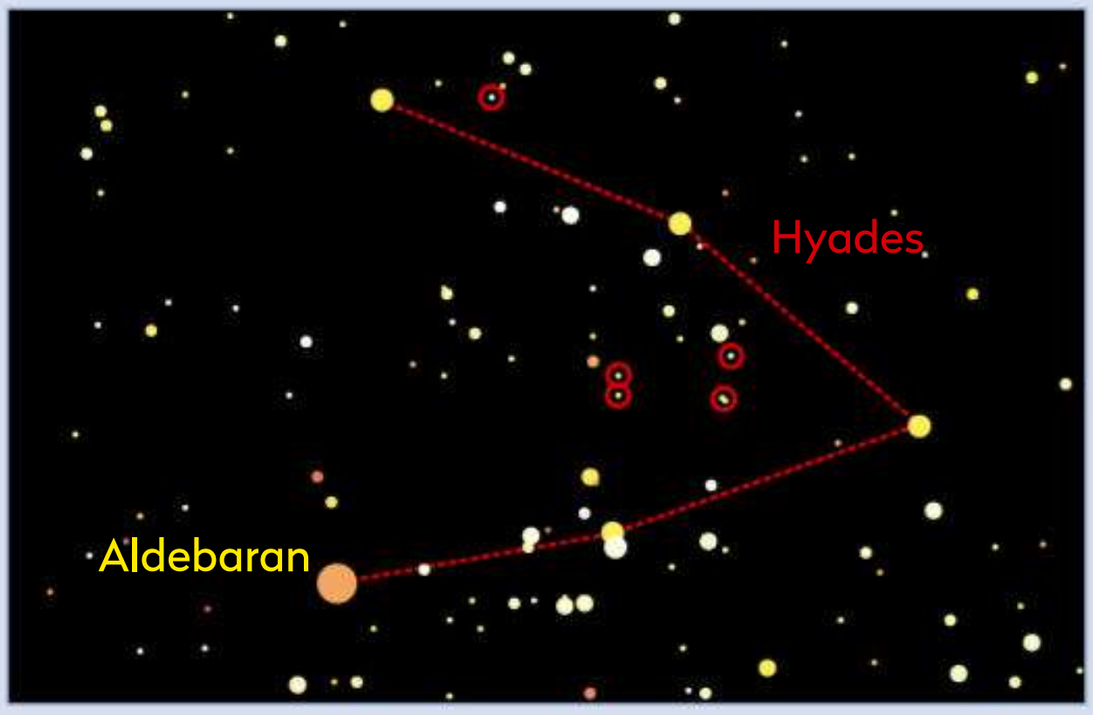
STEP 2

Set the lens to manual. Select the lowest f/number and close by a stop or two to avoid frame edge distortions. Set the camera to 'Manual' mode. If you are using a tracking mount use a mid to low ISO setting, or select a mid ISO value for a fixed mount. A remote shutter release will help to stop any camera shake.



STEP 3

Focus as accurately as possible. The bright star Aldebaran will be good for this and it should show up clearly if your camera has a 'Live View' option. If not, you'll need to focus as accurately as possible through the viewfinder. If you're struggling with Aldebaran, try focusing on bright Jupiter earlier in the evening.

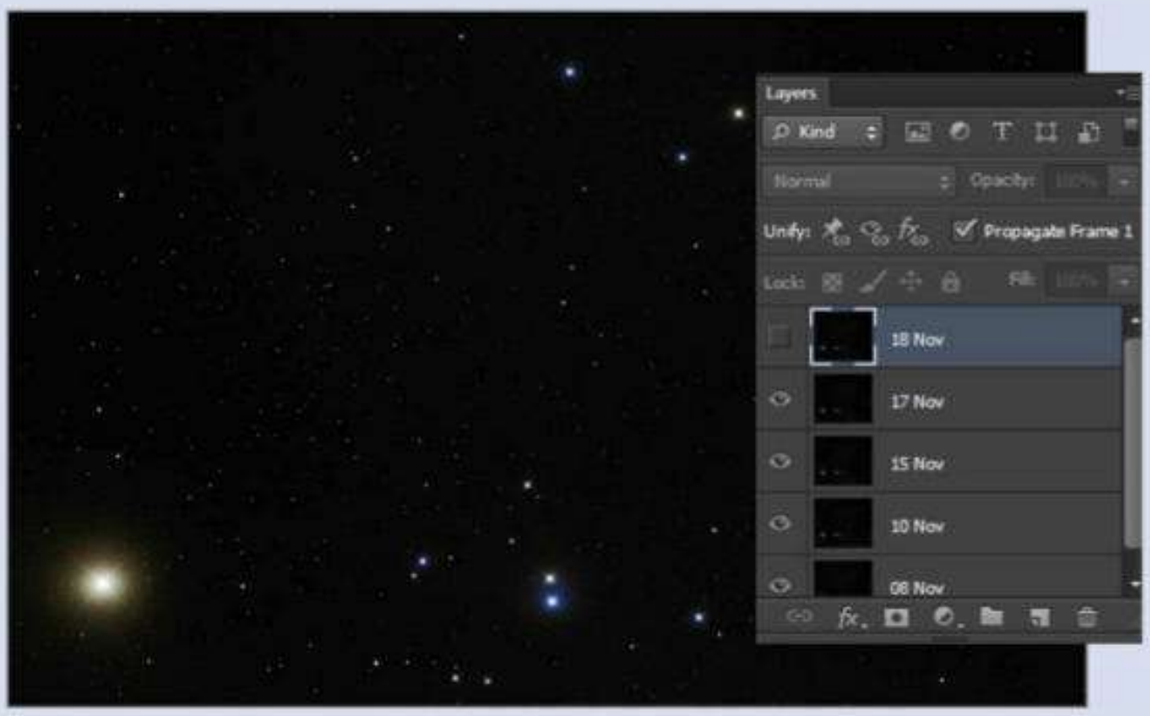


STEP 4

Once you've set the camera and lens, take a test exposure. If you have a static platform, use the 500 Rule to determine the longest non-trailed exposure (as described opposite). Examine the result and look for the mag. +8.0 stars we've circled here. If you can see them, then you are good to go for imaging Ceres.

STEP 5

If you're using a tracking mount, your exposure time is limited by the accuracy of the mount's drive, polar alignment and the sky's brightness. A lower ISO will help bring out the redder hues of the ancient Hyades stars. Typically, bracketing your exposures to 30", 60" and 90" will give you a good range of results to pick from.



STEP 6

Try to image the Hyades on as many clear nights as possible using the same setup. Keeping a similar orientation makes life a lot easier. Load your results into a layer-based editor, aligning the stars between layers. Flicking between layers will reveal Ceres's movement as it tracks in front of the Hyades stars.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Using a histogram to improve nebulae images

Enrich a nebula's colours and add depth to the background with photo-editing software

▲ Before: the original stacked nebulae image of 78 images is too green and lacks impact

When you take an image with a camera, in a perfect world you would get every exposure spot-on, meaning there would be no need to make any further adjustments. But the reality is that we nearly always need to make adjustments after taking photographs, usually using our preferred photo-editing software. In most cases it's a matter of studying a histogram and using the 'Levels' and 'Curves' features or, in the case of PaintShop Pro, an actual 'Histogram adjustment' tool.

The histogram itself is simply a way of showing the varying light levels captured in your image from the dark tones on the left (the 'Blacks') to the white highlights on the right (the 'Whites'). A bump in the middle, representing the middle tones, can also be adjusted. The histogram can also be used for adjusting the individual 'Red', 'Green' and 'Blue' (RGB) colour levels in the same way, making it a very flexible and powerful tool in your photo-editing armoury.

In this month's article we will look at how to use PaintShop Pro's 'Histogram adjustment' tool to improve the colours in a nebulae image. As an example, we are using an already stacked image of the North America and Pelican Nebulae (above).

▲ After: following colour adjustments to the nebulae and background darkening, the image of the North America and Pelican Nebulae is transformed

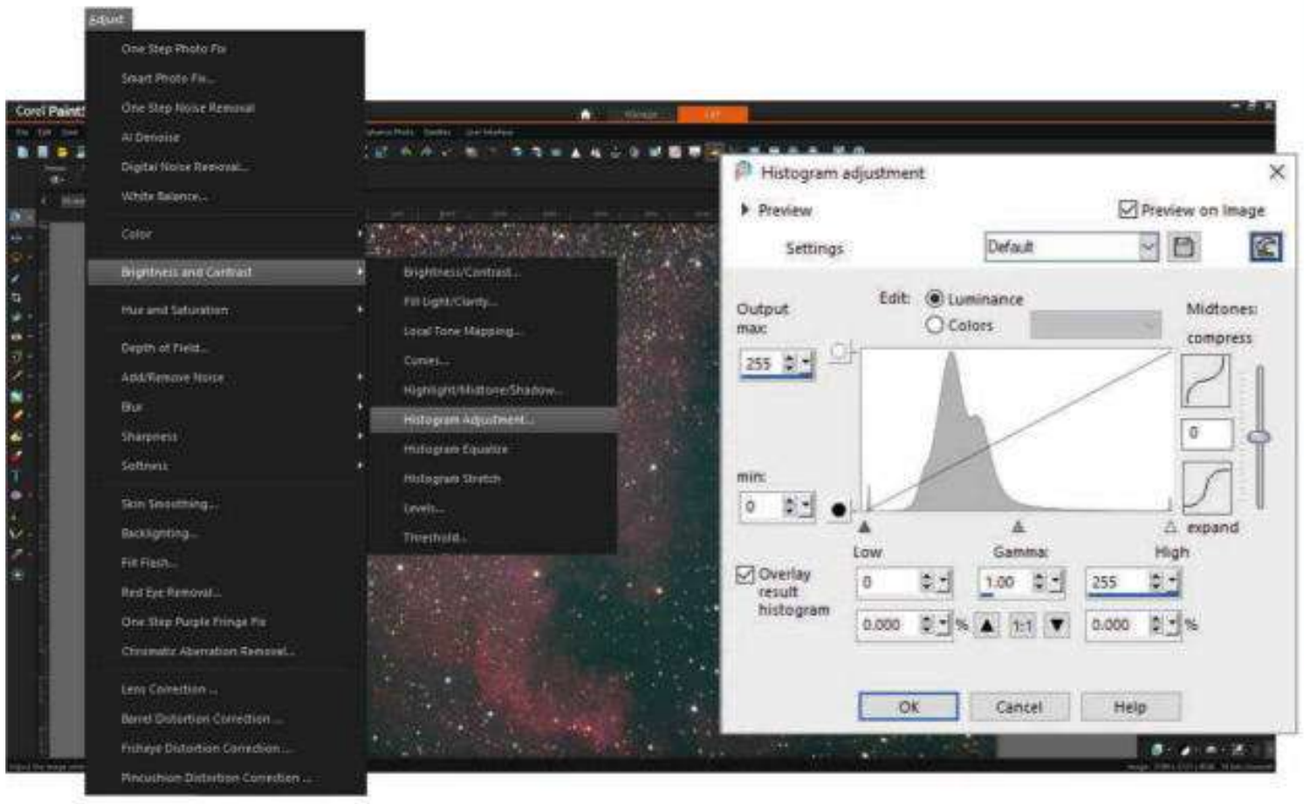
Paul Money is an astronomy writer and broadcaster, and is reviews editor for *BBC Sky at Night Magazine*

ALL PICTURES: PAUL MONEY

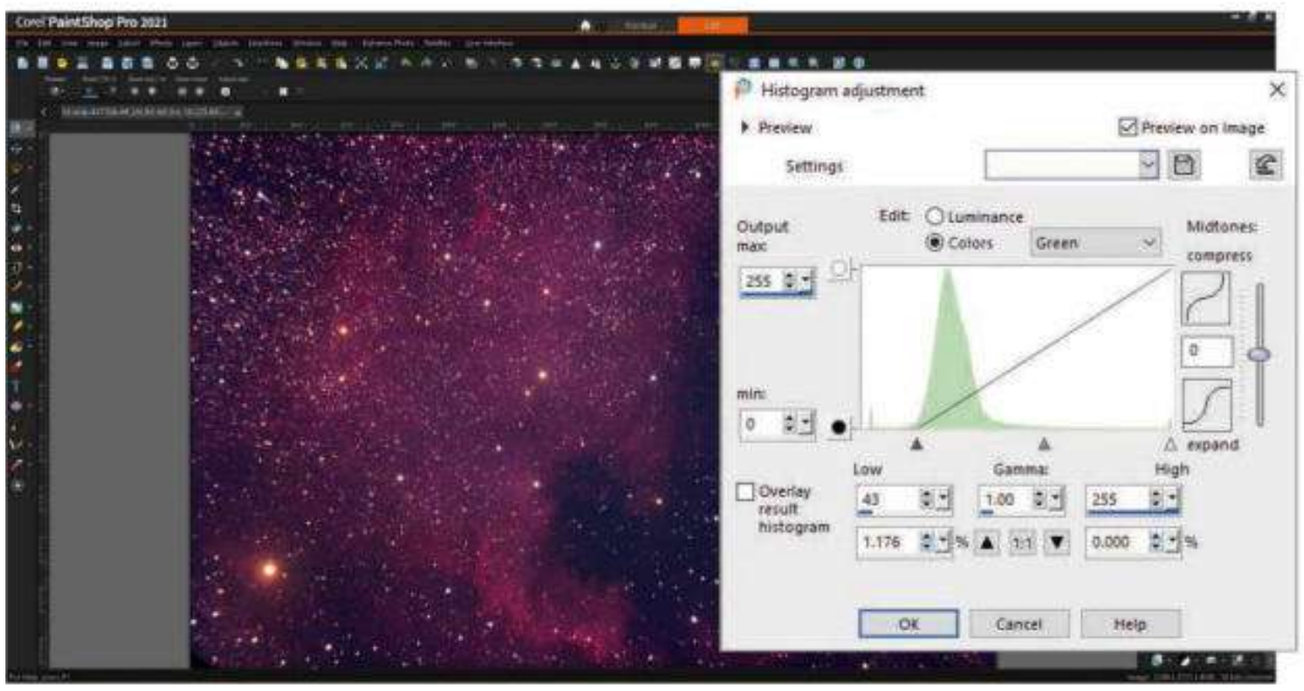
Start on green

The stack of 78 images was taken with a modified Canon 300D DSLR camera through a telescope. As the resulting stack is a little green and lacklustre, the first action in PaintShop Pro is to select and click the following from the top menu: 'Adjust > Brightness and Contrast > Histogram adjustment'. This brings up the 'Histogram adjustment' box (as shown on the right-hand side in Screenshot 1). There are plenty of options here, so first ensure you tick the 'Preview on image' so you can see any changes taking place live on the screen. For now, the rest of the options can be left as they are, but the first job is to deal with the greenish tinge.

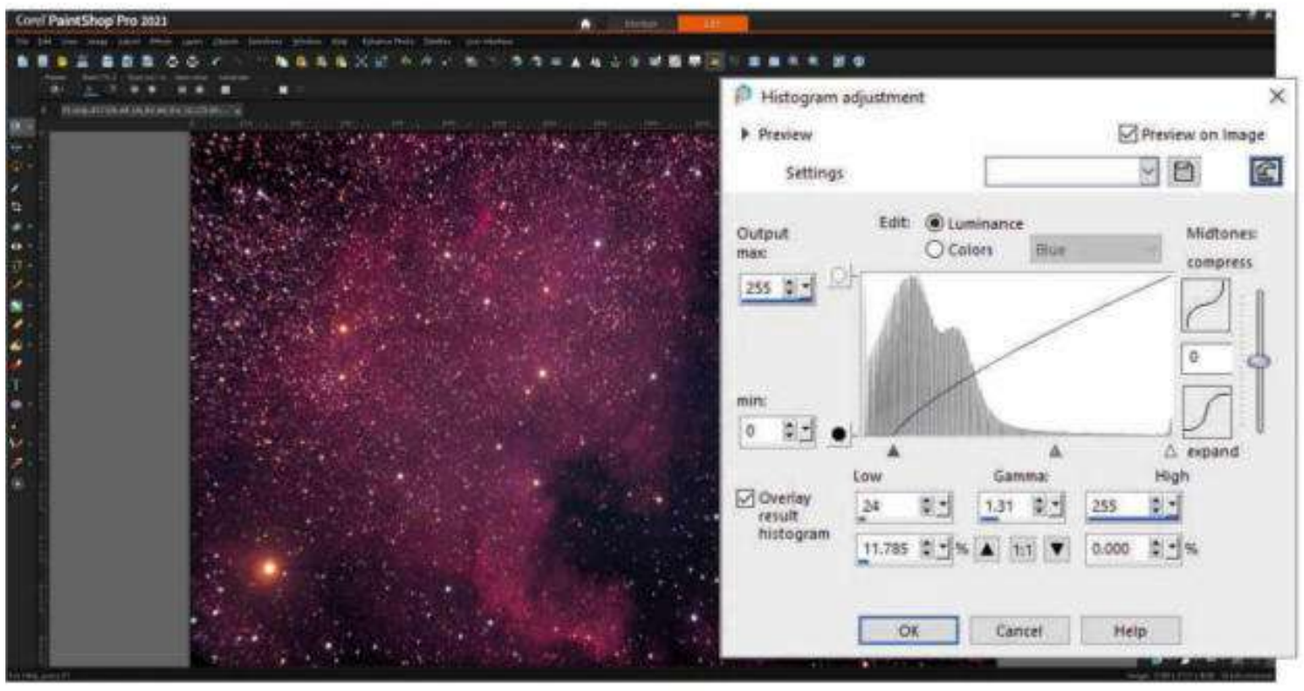
To do this select 'Colours' and then 'Green' from the drop-down list in 'Histogram adjustment' box (See Screenshot 2). This shows the histogram for the green part of the image, so now use your mouse to click and hold the left-hand black adjustment handle at the base of the histogram and carefully slide it to the right until it's close to the start of the green section. The green is now darkened, removing the cast, but it's showing up some blue in the image that you



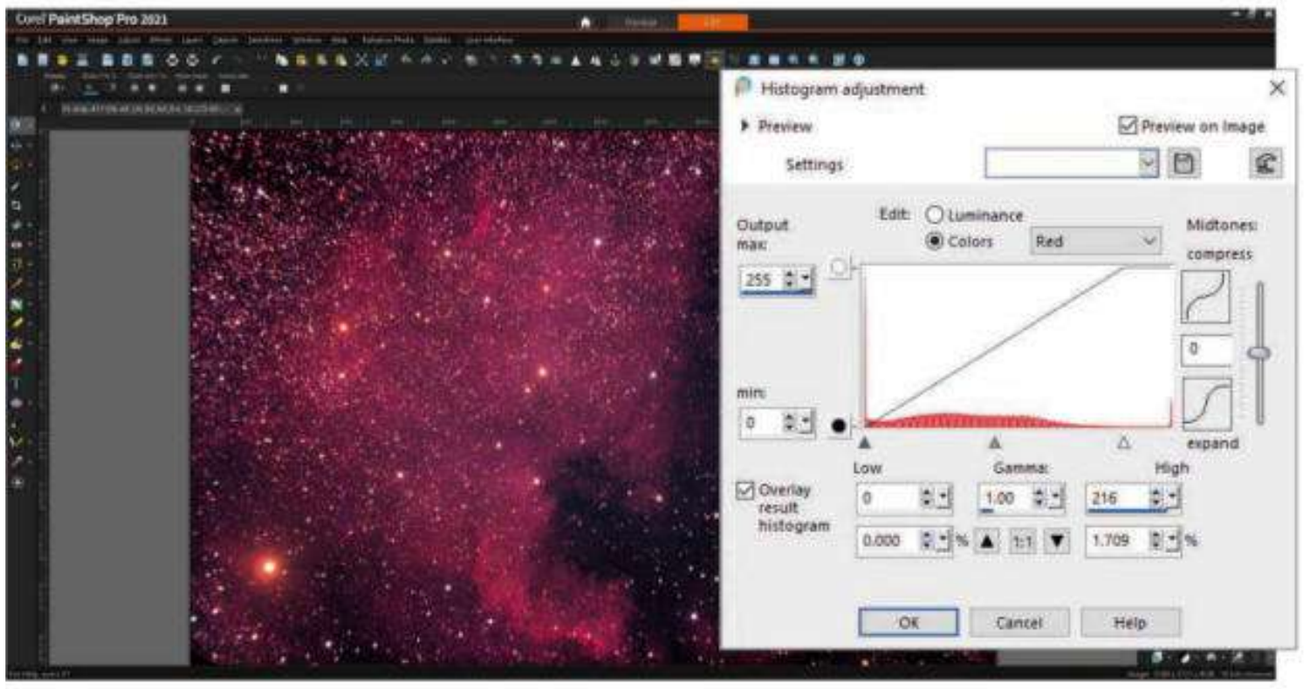
▲ **Screenshot 1: Locate the 'Histogram adjustment' box in PaintShop Pro**



▲ **Screenshot 2: Tweak the green in the image by clicking 'Colours > Green'...**



▲ **Screenshot 3: ...and then select 'Blue' to remove any unwanted blue cast...**



▲ **Screenshot 4: ...and 'Red' to boost the hydrogen-alpha colours**

3 QUICK TIPS

1. Always make a series of small adjustments rather than one big one.

2. Make sure the settings tab is either empty or press the 'Reset to default' button.

3. Don't be afraid to explore the other options in the 'Histogram adjustments' box to further enhance your image.

might not want. To deal with this, keep the 'Histogram adjustment' box open and repeat the steps for the 'Green' adjustments, but instead choose 'Blue' from the drop-down list and adjust it slightly (See Screenshot 3). In both the 'Green' and 'Blue' sections, make subtle adjustments until you're happy with the result and then click 'OK' at the bottom of the box to apply them to the image.

Remember to reset

If the image still looks a little dim, you can adjust it by re-opening the 'Histogram adjustment' box. If the 'Settings' menu says 'Last used' then press the 'Reset to default' to the far right of the box, otherwise the last set of adjustments will be applied again, and you don't want that. The 'Reset to default' sets the 'Histogram adjustment' function to the default of 'Luminance', which allows you to adjust the black adjustment handle at the left and slide it slightly to the right. Again, do this in small increments and watch carefully how the image changes until you're happy with the result. Although this has darkened the image slightly, you can amend this by moving the middle 'Gamma' adjuster a little to the right to change the curve of the histogram. Again, do this in small adjustments until you're happy with the result.

At this stage you haven't needed to move the white adjustment handle for this particular image, but it may benefit from a slight adjustment. Remember, it is down to personal taste how much you push the adjustments. When you're happy, click 'OK' to finish the 'Luminance' adjustment.

The image has been improved, but if you'd like the nebulae to be a little redder, you can now open the 'Histogram adjustment' box again and click 'Select > Colours > Red' (See Screenshot 4). This time, move the white adjustment handle inwards a little at a time, watching how the image changes. Once you're satisfied, click 'OK' to close the box.

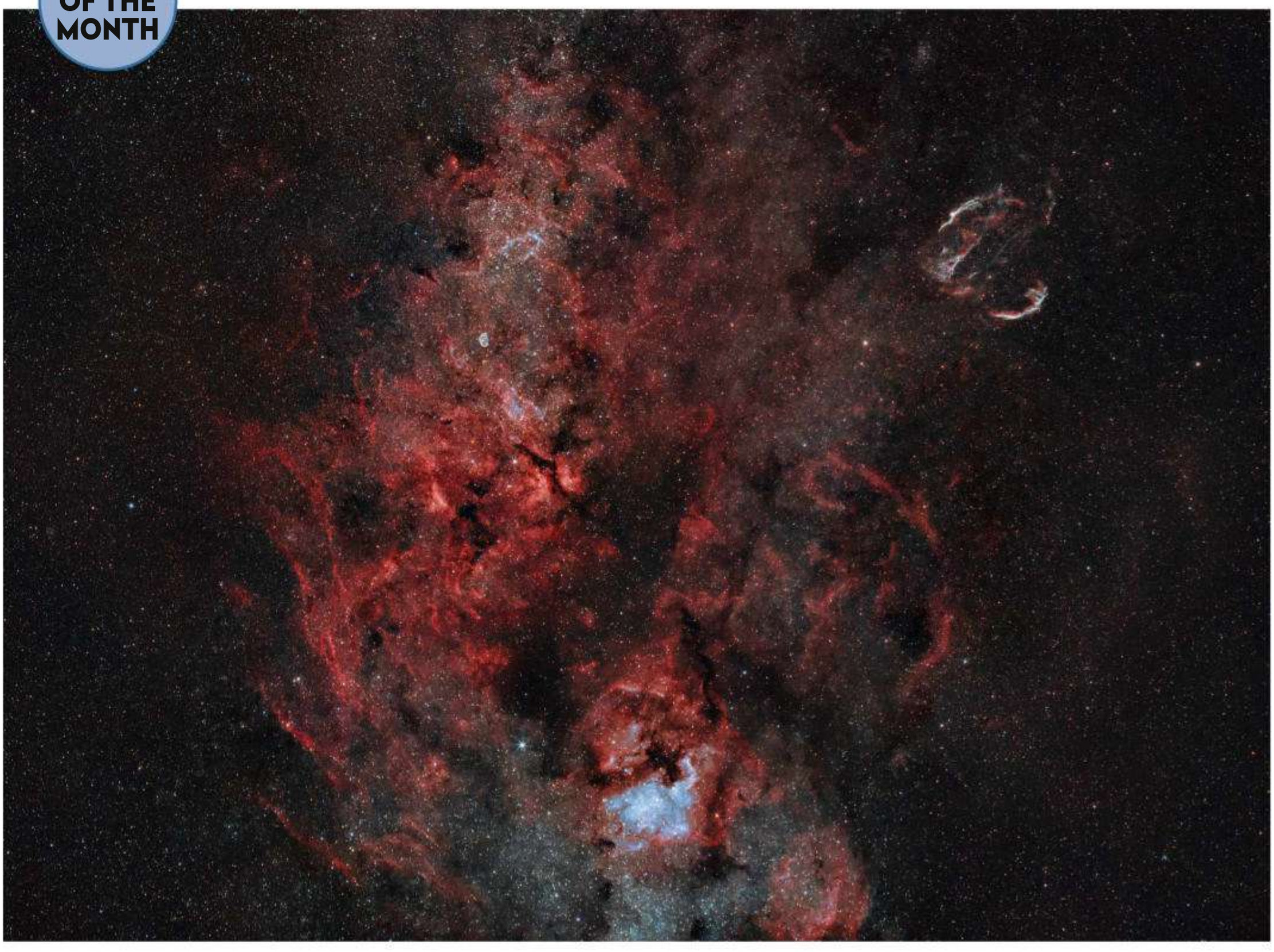
These simple steps have removed the green and slight blue cast, darkened the background to a more natural view of space and brought out the hydrogen-alpha (Ha) red emission of the nebulae, all by using one tool to make multiple small adjustments. The image can be further processed, if necessary, using the 'Saturation' tool but, for now you can enjoy the final, processed image of the North America and Pelican Nebulae (see main picture, left).

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More ONLINE
A gallery containing these and more of your images

PHOTO OF THE MONTH

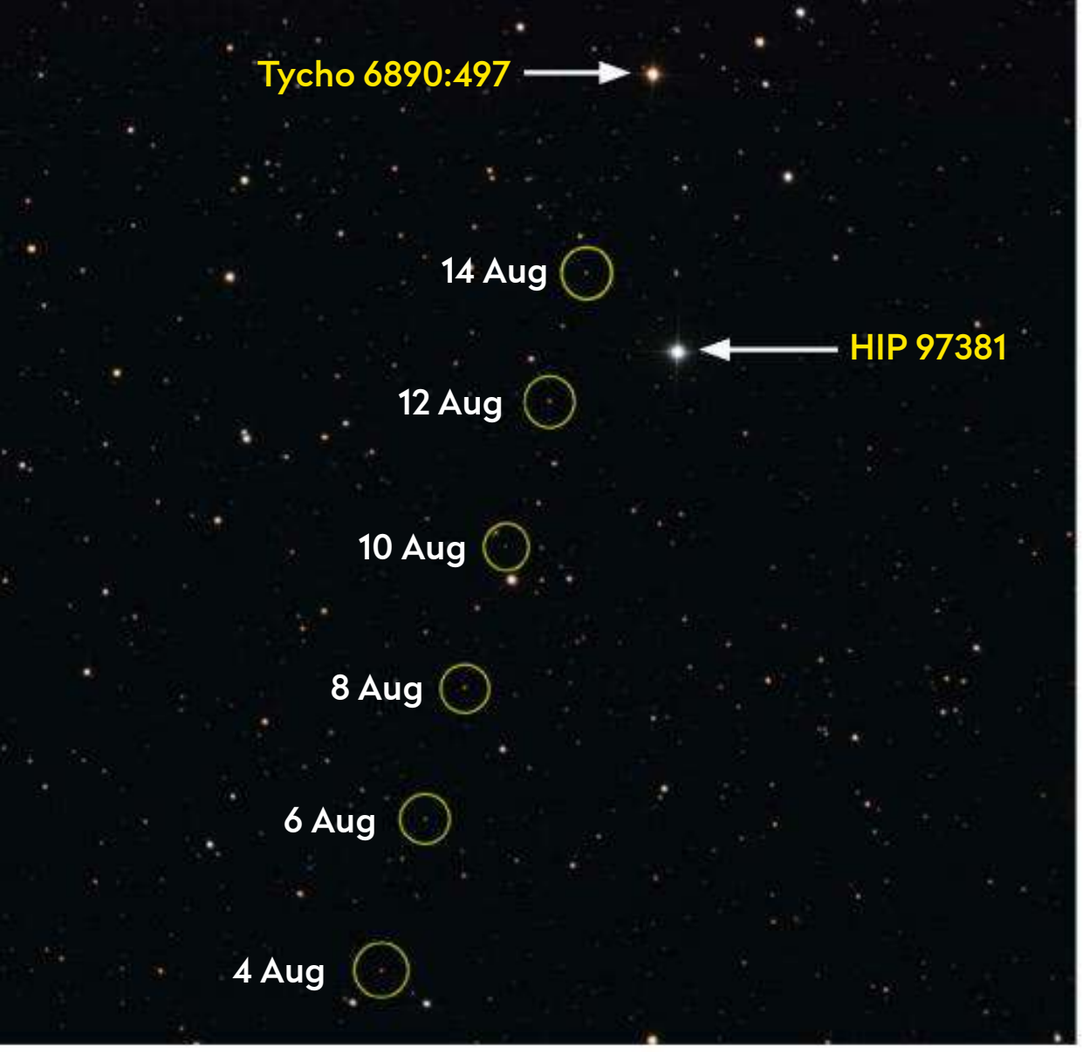


△ The Cygnus constellation

Jeffrey Horne, Nashville, USA, June 2020 and August 2021

Jeffrey says: "Last year I wanted to take a wide shot of Cygnus, with long sub exposures (20 minutes each) to see what kind of faint nebulosity I could pick up. I was so delighted by what I saw that I decided to reframe it this year as a two-panel mosaic that would show the region's entirety. This image is a combination of last year's data with this year's."
Equipment: ZWO ASI2600MC Pro camera, Canon 50mm USM 1.4 lens, Sky-Watcher EQ6R-Pro mount
Exposure: 40h 20' total
Software: Astro Pixel Processor, PixInsight, Photoshop

Jeffrey's top tips: "Shooting with a one-shot colour camera can be challenging in a city, but with enough forethought and integration time, you can get the results you want. I battle light pollution with dual-narrowband filters like the Optolong L-eXtreme, which allows me to do long exposures (20 minutes). To avoid over-exposed stars, I do a round of shorter exposures (60–90 seconds) with a broadband filter like the Optolong L-Pro. Using PixInsight's Starnet++ feature I remove the stars from the image, then use 'Layers' in Photoshop to add the broadband stars to the narrowband nebula. This means you get the best of both worlds: faint nebulosity, and colourful and properly exposed stars."



△ Pluto's movement

Kfir Simon, remotely via Tivoli Farm, Namibia, 4–14 August 2021

Kfir says: "This is exactly how the dwarf planet Pluto was originally discovered in 1930 by Clyde Tombaugh – by comparing two (or more) images and 'blinking' them to see the movement."

Equipment: FLI ProLine 16803 CCD camera, Phillip Keller 16-inch Hypergraph, ASA DDM 160 mount, Sky-Watcher EQ6-R mount **Exposure:** 6x 3' **Software:** Maxim DL, Photoshop

△ The Milky Way over Logan Rock

Simon Hudson, Treen, Cornwall, 29 August 2021

Simon says: "Logan Rock in Cornwall is a place I will return to again. It's such a great spot for astrophotography."

Equipment: Nikon D850 DSLR camera, Sigma 14–24mm lens, Sky-Watcher Star Adventurer mount **Exposure:** sky: ISO 2000, f/3.5, 2x 120"; foreground: ISO 2000, f/2.8, 2x 120" **Software:** Photoshop

◁ Close-up of globular cluster M3

Vitali Pelenjow, Kernen, near Stuttgart, Germany, March–May 2021

Vitali says: "It was fascinating to reveal the faint stars and tiny galaxies around this beautiful globular cluster as the telescope gathered more and more data."

Equipment: ZWO ASI2400MC camera, Celestron 11-inch EdgeHD Schmidt-Cassegrain, 10 Micron GM1000 HPS mount **Exposure:** 912x 180" **Software:** PixInsight

△ The Perseids over the Geoneedle

Kevin McDonagh, Exmouth, Devon, 13 August 2021

Kevin says: "The forecast showed a window of opportunity free from cloud between 10pm and 12.15am. I took 456 shots and managed to capture these 13 meteors."

Equipment: Canon 6D DSLR camera, 14mm Samyang lens, Manfrotto tripod **Exposure:** ISO 3200, f/2.8, foreground: 1/60", sky: 15" **Software:** Lightroom, Photoshop

The Elephant's Trunk Nebula in hydrogen-alpha ▷

Michael Bate, Milton Keynes, 28 August 2021

Michael says: "This is probably the image I'm most proud of to date, having only recently started using an Ha (hydrogen-alpha) filter. I'm amazed at the details brought out in the huge column of interstellar gas and dust."

Equipment: ZWO ASI1600MM camera, Sky-Watcher 200PDS Newtonian, Sky-Watcher HEQ5 Pro mount **Exposure:** 15x 360" **Software:** DeepSkyStacker, Affinity Photo

◁ The Pinwheel Galaxy

Hannah and Joel Da Costa, Preston, 6 and 7 April 2021

Hannah and Joel says: "We bought our telescope just before lockdown last year. We think this is our best shot so far."

Equipment: ZWO ASI294MC Pro camera, Celestron NexStar Evolution 6 Schmidt-Cassegrain **Exposure:** 6.5h total **Software:** APT, DeepSkyStacker, Photoshop, DeNoise AI

▽ Jupiter with triple moon transit

Sona Shahani Shukla, New Delhi, India, 15 August 2021

Sona says: "This was a rare triple moon transit by (on the right) Ganymede, Europa and Callisto. I also captured Io emerging from the left limb."

Equipment: ZWO ASI178MC camera, 8-inch Sky-Watcher 200P Dobsonian **Exposure:** 5.49ms, gain 302, (4,835 frames captured at 76fps, stacked at 40%) **Software:** SharpCap Pro, RegiStax, Photoshop, AutoStakkert!

△ The Lion Nebula

Emil Andronic, Bushey, Hertfordshire, 1 June–15 July 2021

Emil says: "A while ago I thought about capturing some targets that are a little out of the ordinary and the Lion Nebula was the first on my list. When the first sub rolled in, I was extremely pleased to see so much signal in a single 300-second sub-exposure."

Equipment: ZWO ASI294MM Pro camera, Astro-Tech 106LE triplet refractor, Sky-Watcher EQ6-R mount **Exposure:** Ha 80x 300", OIII 60x 300", SII 50x 300" **Software:** Astro Pixel Processor, PixInsight, Photoshop

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Whether you're a seasoned astro-photographer or a beginner, we'd love to see your images. Email them to **contactus@skyatnightmagazine.com**. Ts&Cs: **www.immediate.co.uk/terms-and-conditions**

hama

We've teamed up with Modern Astronomy to offer the winner of next month's Gallery a Hama Lens Pen, designed for quick and easy cleaning of telescope optics, eyepieces and camera lenses. It features a retractable brush and non-liquid cleaning element. **www.modernastronomy.com • 020 8763 9953**

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We see if the sturdy build of Altair's 8-inch F4 Photo Newtonian telescope is matched by its performance 87

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HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

PLUS: Books on the Big Bang theory debate and the patterns of the cosmos, plus a roundup of recommended gear

Our experts review the latest kit

FIRST LIGHT

Altair 8-inch F4 Photo Newtonian telescope

A reliable Newtonian, with impressive light-gathering ability, that's tailored for imaging

WORDS: TIM JARDINE

VITAL STATS

- **Price** £540
- **Optics** BK7 glass mirror
- **Aperture** 203mm (8-inch)
- **Focal length** 800mm
- **Focuser** 2-inch Crayford with 1:10 dual speed transmission
- **Extras** Finderscope, 35mm extension tube
- **Weight** 8.4kg
- **Supplier** Altair Astro Ltd
- **Tel** 01263 731505
- **www.**altairastro.com

As its name implies, the Altair 8-inch F4 Photo Newtonian is a reflecting telescope made to be used primarily with a camera for astrophotography. Its construction consists of a sturdy steel tube, rings and fittings, and even without a camera it weighs around 8.4kg; it'll require a strong, stable mount to support it for best results. The tube is 730mm long and 230mm wide, and presents quite a lot of surface area, but our observatory provided a sheltered environment from any wind that might nudge the telescope and spoil the images being taken.

Once the tube was mounted and balanced, we turned our attention to collimating, or aligning, the mirrors. This is a vital part of using a reflector, and at its fast focal ratio of f/4 it's important to be accurate as any errors will quickly show up as distorted stars in images. For this type of instrument, we would typically check the collimation before each use, even though it was mounted on a pier in an observatory. If the scope was being removed from the mount after each session it would be even more important to check the mirror alignment each time. This process may be off-putting to those new to astrophotography or unfamiliar with reflectors, but although a little tedious the adjustment is not difficult and it definitely becomes easier with practice and a couple of additional tools to help.

A question of collimation

The primary mirror cell is a fairly standard design; three black sprung adjusters at the rear exert a push and pull influence on the primary mirror, which once aligned is held in place by three white locking screws. This procedure of adjusting the primary mirror is quite straightforward, but we found that adjusting the secondary mirror – via three Phillips screws in the mirror holder on the spider vane – while viewing the adjustments through the collimation tool required a steady hand and great care to avoid dropping the screwdriver onto the primary mirror.

Once we were happy that both mirrors were correctly aligned, we used the supplied 35mm extension piece to fit an eyepiece and perform a ▸

12V fan

The rear of the primary mirror cell incorporates a 12V fan that blows air onto the mirror and up around the sides into the tube. This acts as an aid to quickly cooling the mirror and steel tube down before use. A battery case for 8x AA size batteries is also included.

FIRST LIGHT

Over-sized secondary mirror

The diagonal, or secondary mirror is optimised for photography by being larger than standard. With only a minimal loss of contrast at the camera, the 70mm mirror ensures good illumination for today's larger sensor astro cameras, when it's used in conjunction with a good quality coma corrector.

Finderscope

An 8mm x 50mm straight-through finderscope is supplied with the telescope, a straightforward unit with two adjusting screws for alignment and crosshairs that ensure accurate pointing. The mounting shoe could alternatively be used for a separate guidescope, which is probably more useful on this instrument than a finderscope.

Rings and dovetail bar

The 33.5cm dovetail bar in Altair's traditional red colouring attaches to the robust steel tube rings to firmly hold the telescope with enough separation between the rings for steady balance. The flat areas on top of the rings with standard threaded holes could be used for extra accessories or an additional guidescope.

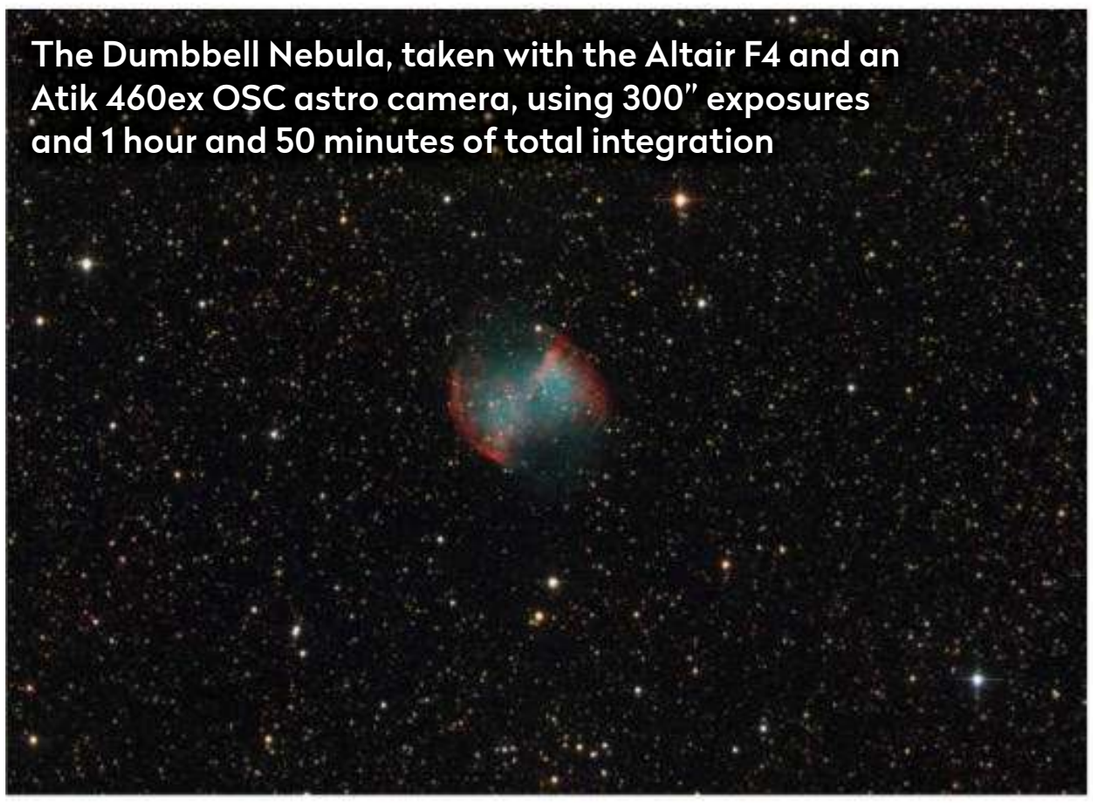
Focuser

The Crayford-style focuser is basic but quite user friendly. It has a 1:10 reduction gear and extends 35mm, with metric and imperial graduations on the drawtube. It has separate thumbscrews to lock the focuser in position and to adjust the tension, while dual thumbscrews clamp your camera nosepiece in place.

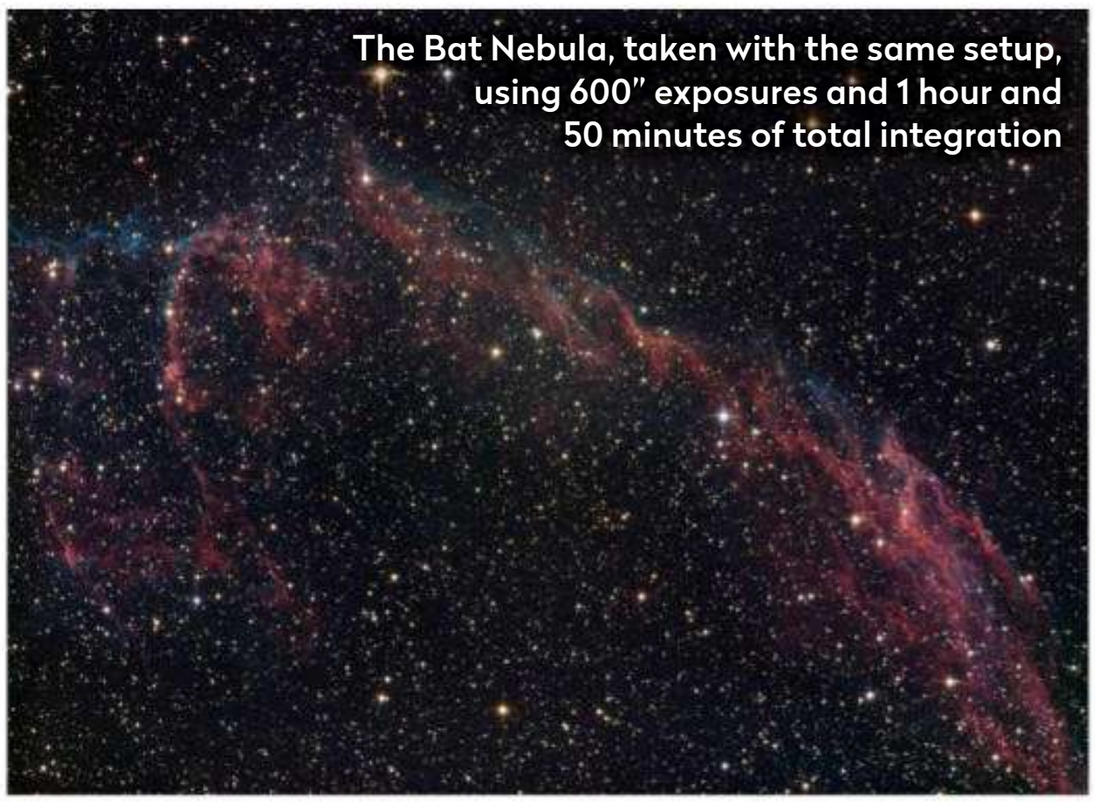
@THESHED/PHOTOSTUDIO X 4, TIM JARDINE X 2

Superior optics

The key to the best astronomical views and photographs is the light-gathering ability of the telescope. At 203mm, or 8-inch diameter, the primary mirror in the Altair F4 Photo Newtonian presents an ideal compromise between size and manageability. There are several features of the optics that we like, and which add up to help create better images. Without glass lenses to distort the incoming light, reflecting scopes do not suffer from chromatic aberration and can therefore be used with DSLR and one-shot-colour astro cameras without annoying halos spoiling bright stars and planets. Both primary and secondary mirrors in this Altair scope have coatings to enhance the reflectivity of the mirrors, and the fast focal ratio of f/4 makes them ideal for gathering large amounts of signal, or data, in the shortest time. Shorter exposures are easier to guide, produce less image noise and present less challenges than traditional, long deep-sky exposures. The enlarged secondary mirror allows for 100 per cent illumination of APS-C-sized cameras using a coma corrector.



The Dumbbell Nebula, taken with the Altair F4 and an Atik 460ex OSC astro camera, using 300" exposures and 1 hour and 50 minutes of total integration



The Bat Nebula, taken with the same setup, using 600" exposures and 1 hour and 50 minutes of total integration

▸ visual confirmation. Although there is no technical reason the telescope couldn't double up as a visual instrument if desired, the amount of coma that is inherent in f/4 primary mirrors makes the view at the eyepiece quite distorted outside the centre of the view, with stars being stretched out towards the edges. We felt that this would make prolonged visual sessions uncomfortable unless an additional correcting lens for the eyepieces was available.

Staying focused

As far as astro imaging is concerned, that inherent coma, which can spoil visual observing, is easily dealt with by adding a coma corrector in front of the camera. We borrowed a 0.95x multi-purpose coma corrector to use with our camera and set about capturing some images. Reflecting telescopes like this, with traditional spider vanes, produce diffraction spikes on bright stars and, love or loathe them, they provide a useful focus reference. The shallow depth of field for this setup makes an auto-focuser seem appealing (which could be retro-fitted), but we found that when we were manually focusing, the focus held well over our session, once it was locked in place.

With the Dumbbell Nebula, M27, as our first target we used the rich surrounding star field to check star shapes into the corners of our photograph. Our imaging camera has quite a small sensor compared to the larger sizes the scope can support, but the stars looked good – right into the corners of the view. Some short 5-minute exposures reminded us of the attraction of fast Newtonian imaging astrographs, showing clean, high signal data and good colour. The images had an almost organic feel that comes from the light-gathering power of an 8-inch mirror.

The Altair 8-inch F4 Photo Newtonian provides a useful base unit and when it's combined with selected accessories it makes for a strong imaging setup which is capable of producing stunning deep-sky photographs.

KIT TO ADD

1. Newtonian coma corrector 0.95x Maxfield

2. Altair MG60 guidescope

3. Altair Hypercam deep sky camera

VERDICT

Build & design	★★★★☆
Ease of use	★★★½☆
Features	★★★★☆
Imaging quality	★★★★☆
Optics	★★★★☆
OVERALL	★★★★☆

Our experts review the latest kit

FIRST LIGHT

Vixen Polarie U Star Tracker

A lightweight star-tracking device that will deliver detail in a range of astrophotos

WORDS: CHRIS GRIMMER

VITAL STATS

- **Price** £577.50
- **Payload capacity** 2.5kg
- **Tracking rates** Sidereal, 0.5x star speed, solar, lunar; Northern and Southern Hemisphere-compatible
- **Power requirements** 4x AA batteries or USB Type-C
- **Dimensions** 88mm x 72mm x 110mm
- **Weight** 575g
- **Supplier** Telescope House
- **Tel** 01342 837098
- **www.**telescopehouse.com

ALL PICTURES: @THESHED_PHOTOSTUDIO

Vixen was among the first manufacturers to launch a lightweight star tracker into the market with its Vixen Polarie. With a vast array of such trackers now available, we took their latest offering, the Vixen Polarie U for some dark-sky testing. It is sold as a standalone unit that does not include an equatorial mount or a dedicated polar scope, which are optional extras. For this review we were loaned both additional items.

When we unboxed the Polarie we found a very compact and reasonably light mount, in fact 20 per cent lighter than Vixen's previous model. The housing of the Polarie U is plastic, but it feels very rigid and robust and doesn't flex when pressed. On the underside of the tracker there is a 3/8-inch thread with a 1/4-inch adaptor. This enables the mount to fit straight onto a tripod, or with the adaptor onto a ball head mount or similar. The bottom of the mount also doubles as a foot, which is compatible with Vixen's multi-use ball head, and this allows it to attach directly without the need to screw on.

Straightforward controls

The tracker only has three buttons on the front: an 'N' and 'S' slider to select either the Northern or Southern Hemisphere (which also acts as a power button); a button to turn the Wi-Fi on and off; and a 'Mode' selection button. Lights on the mount highlight which 'Mode' is selected (there is no LCD screen). This makes identification at night straightforward. On either side of the mount there is space for 2x AA batteries (four in total), a guide port, a USB Type-C connection and a port for connecting your camera. Vixen has put a lot of thought into the layout; the Polarie U is easy to operate in the dark, and all its lights are faint and red.

Setting up was very straightforward with no additional assembly required other than attaching the Polarie U to the ball head mount. A further ball head will need to be attached to the top of the mount to enable the camera to be pointed. The camera mount is attached to the Polarie U by two thumbscrews so this can be fully detached (a carry-over feature from Vixen's previous model), which allows the ball head and camera to be attached easily.

We were able to align on Polaris (Alpha (α) Ursae Minoris) in seconds using the plastic sighting tool supplied and the smooth optional Fine Adjustment head. Trying this again with a standard photography ball head proved a little more difficult, so a geared head would be beneficial. This rough alignment allowed us to obtain multiple-minute exposures with ▸

Connection and control

The standout feature on the Polarie U is the ability to connect your camera directly to it and then control the entire setup from the Polarie U app. The app is available to both Android and Apple users and is free to download. To set this up, you simply press the Wi-Fi button on the mount and then open the app on your phone to follow the steps and connect wirelessly to the app; proving very straightforward even in the dark. The app gives you access to change the tracking mode, so you don't have to touch the mount. There is also a built-in intervalometer (an advanced remote shutter release) that allows you to set your exposure time and number of shots, which is useful if you have purchased the appropriate camera connection cable. This is enough to cover any imaging goals. The app has been designed to be used at night as the colour can be set to red and made very dim, which will help maintain your night vision and not upset any nearby astronomers.

Polar finder

The Polarie U comes with a plastic sight that fits on the hot shoe bracket (flash mount) on the tracker. This enables a very quick alignment to Polaris. The process is ideal for shooting wide-angle views when precision isn't needed. This adaptor will also fit on the hot shoe of your camera for target-alignment.

Tracking modes

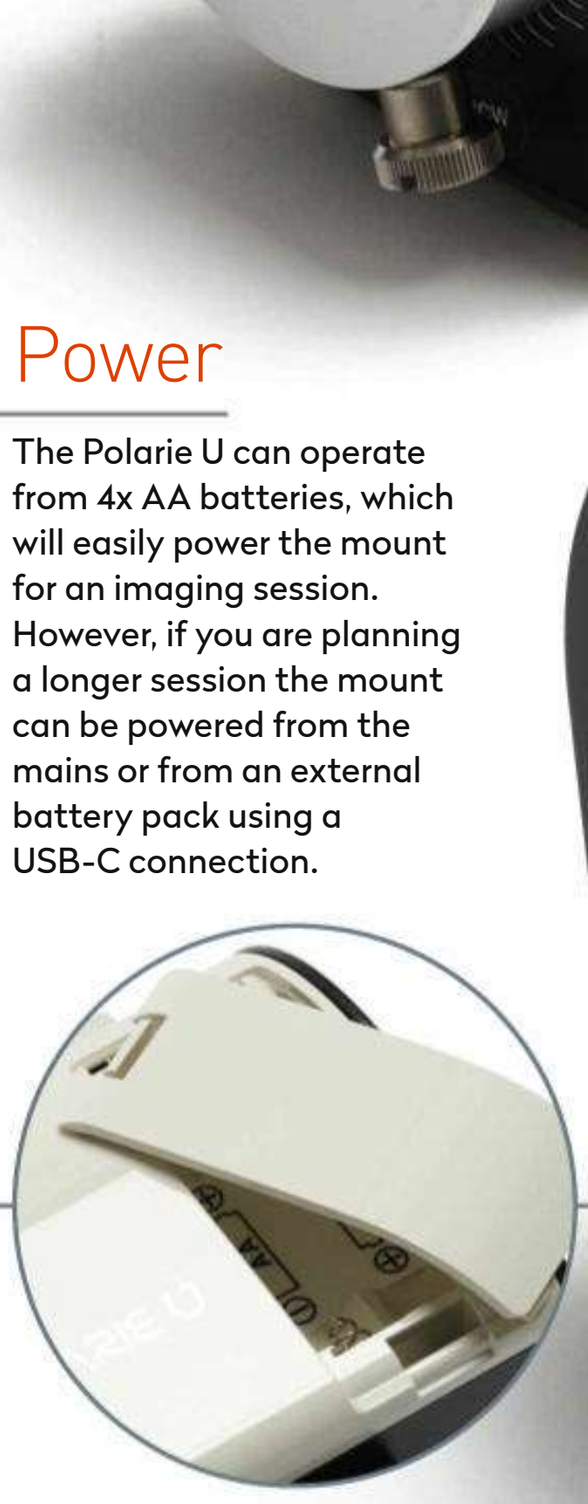
Whether you are looking to capture the Milky Way, the Moon or a timelapse, the Polarie U will track it. Offering sidereal (the rate at which Earth spins on its axis), 0.5x star speed, solar and lunar rates for both Northern and Southern Hemispheres at the simple touch of a button, all astronomical targets are covered.

Mount connections

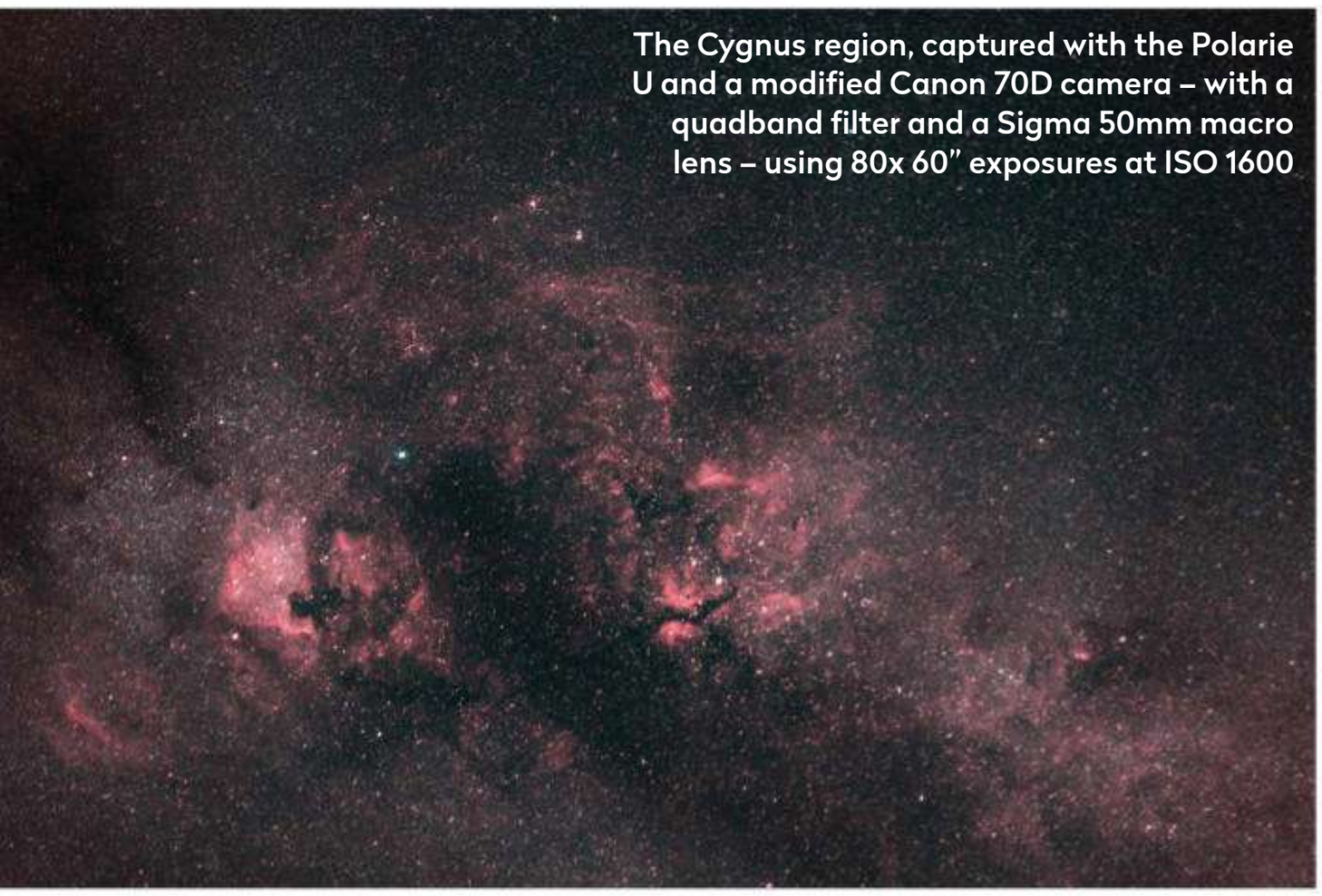
The Polarie U not only has a ⅜-inch photo tripod thread, with an included adaptor to ¼-inch thread to fit any tripod, but it also has two built-in 'feet' to connect to clamp-style mount heads, either in an equatorial position for astronomy or an altaz position for time-lapse photography.

Power

The Polarie U can operate from 4x AA batteries, which will easily power the mount for an imaging session. However, if you are planning a longer session the mount can be powered from the mains or from an external battery pack using a USB-C connection.



FIRST LIGHT



The Cygnus region, captured with the Polarie U and a modified Canon 70D camera – with a quadband filter and a Sigma 50mm macro lens – using 80x 60" exposures at ISO 1600

◄ The Veil Nebula region, taken with the same setup, using 58x 60" exposures at ISO 1600

Guide port

For those looking to achieve longer exposure times, the Polarie U offers single-axis guiding via a guide port on the side of the mount. This will require the use of separate software and a guidescope, so the total payload weight should be considered if you are planning this

► a 14mm wide-angle lens. We then attached the optional polar scope that enabled us to refine our polar alignment by visually aligning Polaris and two other stars against the image printed within the polar scope. This process was straightforward and was never blocked by the way the polar scope attaches, meaning it could be used with a camera attached.

Using a 150mm lens on a cropped sensor DSLR camera we started to see star-trailing after 60 seconds, despite revisiting our polar alignment. Switching down to a 50mm lens, we found that 60-second exposure shots gave pinpoint stars, but 120-second exposures were beyond our reach. We set the camera running with 90-second and 60-second exposures with both our 50mm and 150mm lens, correcting the polar alignment after swapping the lenses over. Inspecting the images in post processing, we only had to exclude 10 frames from the batch taken with the 50mm lens due to elongated or deformed stars. However, with our 150mm lens weighing in at 1.7kg, we discovered that we had lost 32 of the 90 images we captured due to movement in the exposure, despite it being a very still night.

One of the Polarie U's strongest points is its Wi-Fi capability and app connection (see 'Connection and Control' box, on page 90). Using an optional trigger cable to connect the camera to the mount meant we were able to control it from the Polarie U app and set our exposure time and number of exposures. The benefit of this system is that once you are aligned you do not have to touch the camera again, reducing the risk of knocking it out of polar alignment.

The Polarie U is a very portable star tracker which, when partnered with a solid ball head mount, will enable you to capture the night sky in great detail.

VERDICT

Connectivity	★★★★★
Build and design	★★★★½
Ease of use	★★★★½
Features	★★★★☆
Tracking accuracy	★★★½☆
OVERALL	★★★★½

KIT TO ADD

1. Vixen Polar U polar finder

2. Vixen Polar fine adjustment unit DX

3. Bresser 15kg ball head mount

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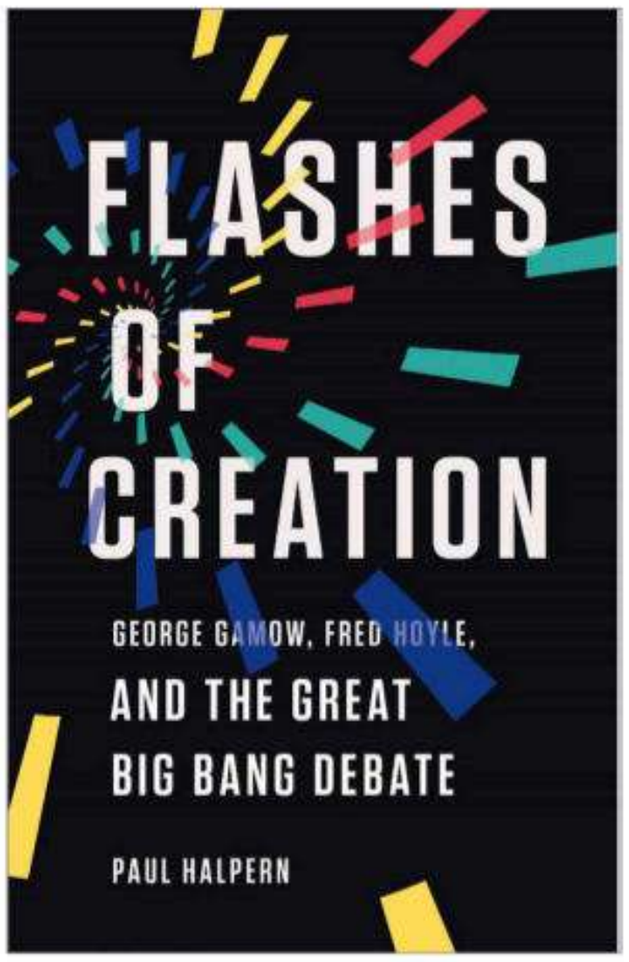


Flashes of Creation

Paul Halpern
Hachette
£22.99 ● HB

The Big Bang theory is happily taken for granted as the established model that describes how our Universe came into being. Indeed, this theory is so mainstream that there's a popular TV series named after it. And yet there was a time in the not-so-distant past when there was much more debate about how everything started, how the elements were created and how they arrived at the abundance seen in our Universe today.

Flashes of Creation describes the lives of two of the giants of the great cosmological debate: George Gamow (1904-68) in the corner of the Big Bang theory and Fred Hoyle (1915-2001) with the steady-state theory. Although many different scientists contributed to the development of each theory, it is often these two interesting figures that are pitted against each other, despite them having few interactions in real life. This is also likely down to their mastery of science communication, both being among the first scientists to use radio and television to connect with the public.

The book starts with their childhoods and the landscape of physics at that time. It then progresses through the lives of both men, and nicely describes how our general understanding of the Universe changed due to key insights and discoveries over the last century. The final chapter concludes with the legacy of these two tremendous thinkers.

The book does not really go into detail about the physics itself, but tells us the human story of how this era unfolded, which is additionally brought to life with quotes from family members and other scientists.

P GRANGER HISTORICAL PICTURE ARCHIVE/ALAMY STOCK PHOTO, A IMAGES/ALAMY STOCK PHOTO

George Gamow (left) and Fred Hoyle (right), two of the heavyweights of cosmological debate

This is something of a limitation to the book: you already have to be familiar with cosmology and some of the other ideas being discussed or you may find yourself needing another resource to understand some of the details. At times the pace of the book could be slow and some details were repeated. Having said this, if you'd like to know more about two of the leading figures in cosmology and the story of how we came to recognise the Big Bang theory as the best interpretation of how the Universe began, then this book is for you. ★★★½☆

***Laura Nuttall** is a senior lecturer in gravitational waves at the University of Portsmouth*

Interview with the author
Paul Halpern

Was Fred Hoyle annoyed that the term 'Big Bang' stuck?

Hoyle coined the term in March 1949 on a BBC radio broadcast, as a way of poking fun at the concept of a universal explosion that no scientist might ever observe directly. When the transcript appeared in *The Listener*, the term began to seep into common use. It was picked up by the *New York Times* and has been popular ever since. Hoyle was aghast that the idea became so widely accepted.

How did Hoyle react to the prospect of being wrong?

Hoyle was brilliant and stubborn, and loved to match his wits against other scientists. But, when his best hunches were cast into doubt, he scrambled to find face-saving alternatives. He tried to promote the idea of 'little bangs' that would create helium more locally, along with iron or graphite needles scattered in space that would generate the requisite microwave background without the need for a Big Bang. By that point, mainstream scientists had stopped taking him seriously.

How much do we now understand about the birth of the Universe?

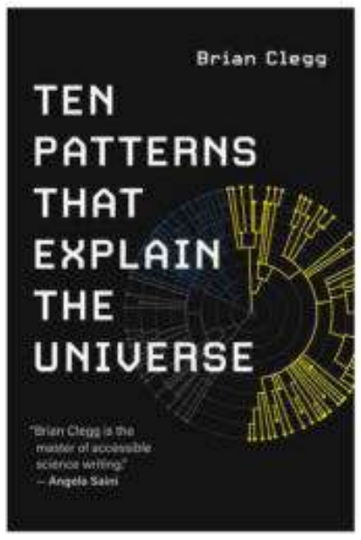
Since the Hoyle-Gamow debate, cosmology has made tremendous progress, thanks mainly to satellites that have mapped out the cosmic microwave radiation in finer and finer detail, along with the Hubble Space Telescope that has tracked the behaviour of extremely distant galaxies. It points to the fact that not only is the Universe expanding, but that the expansion is accelerating. It is truly a golden age of cosmology.

***Paul Halpern** is Professor of Physics at the University of the Sciences, Philadelphia*

Ten Patterns that Explain the Universe

CORE SCIENCE

Brian Clegg
MIT Press
£25 ● PB


Brian Clegg
TEN PATTERNS THAT EXPLAIN THE UNIVERSE
"Brian Clegg is the master of accessible science writing."
– Angela Saini

In the introduction to his new book, seasoned science writer Brian Clegg makes a case for the importance of patterns. The human gift for recognising them, he argues, has been vital to our success as a species. In the past few centuries, it's become the cornerstone of how we understand the Universe.

The book's remit is straightforward: to explain 10 of the most important patterns that have shaped our conception of the Universe. Simple though that sounds, it's a challenge that could come unstuck in the hands of a writer lacking Clegg's scope.

Some of the subjects are inevitable – the Periodic Table that reveals the behaviour of elements, for example, or the 'echoes of creation' left by the early cosmos in the Cosmic Microwave Background – but others are less so.

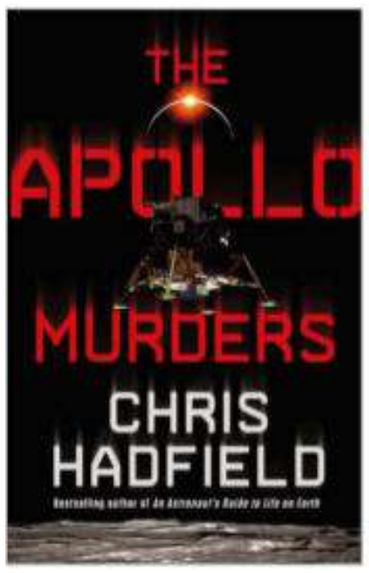
One chapter investigates Hermann Minkowski's graphs depicting the nature of time and space, and the limits of perceptible reality itself. Another describes the Feynman diagrams that provide a visual shorthand for strange events in the quantum realm. Further chapters explore everything from particle trails, weather patterns and the nature of numbers, to the DNA that underlies life on Earth.

Clegg's lucid prose, clever design and an array of photos and illustrations come together to present a procession of intriguing ideas, making this a great, approachable introduction to the bedrock of modern science. ★★★★★

***Giles Sparrow** is a science writer and a fellow of the Royal Astronomical Society*

The Apollo Murders

Chris Hadfield
Quercus
£20 ● HB



Chris Hadfield has an unusually extensive CV. He is not only an accomplished test pilot and astronaut, but a photographer, musician, best-selling author, and now novelist. In this, his first story, what appears to be an accidental death in the run up to the launch of Apollo 18 turns into something much more sinister, and three suspects are trapped aboard the claustrophobic capsule while Cold War tensions heat up.

Told from several perspectives, Hadfield draws on his experience of spaceflight in this alternate-history tale, which is part murder mystery, part political thriller.

Here Hadfield's personal insight really stands out. Details such as the feel of the spacesuit, the headspace of the astronauts and the cabin layout, all put you into the story and make you feel claustrophobia, panic and determination alongside the characters. However, it does rely on having a good background knowledge of spaceflight and the Apollo missions. Without that, the frequent need to Google may take you out of the story a little. The multi-perspective storytelling can also take time to adjust to.

While often compelling, this book could also be streamlined: the minute technical details occasionally over-complicate the story and obscure the bigger picture.

Thriller fans used to a faster pace might be slightly underwhelmed, but Apollo and aeronautics buffs will love the detail and Hadfield's exceptional insight into the experience of spaceflight. ★★★☆☆

***Katie Sawers** is a science writer specialising in cosmology and the history of astronomy*

In Plain Sight

Ross Coulthart
HarperCollins
£16.99 ● PB

In June 2021 the US government released its long-awaited file on so-called 'unidentified aerial phenomena' (UAPs): the unusual objects reportedly seen above Earth for decades. While public reaction was mostly muted disappointment, the saga has brought UFOs again to the fore.

Investigative journalist Ross Coulthart's new book *In Plain Sight* promises to explore the facts (sparse though they may be) regarding UAPs, exploring official government and military lines and detailing how much we actually know. What follows is a dissection of UAP reports and a history of related investigative agencies up to the present.

The subject of UFOs is of course thorny (the 'UAP' rebrand could be seen as a desire for the field to be taken more seriously), but questions remain. Why are there multiple reports of strange aerial objects? Why are government responses so often contradictory? And when do multiple, independent eyewitnesses count as evidence?

Answering these questions, Coulthart produces stupefying testimony from military and government sources, as well as insider evidence apparently never intended for public consumption. Happily, he handles the topic with cynicism, presenting just the facts and at times debunking the seemingly impenetrable evidence himself. It becomes not just a discussion of whether aliens have visited Earth, but an investigation into aerial objects that the US government has admitted it cannot identify (extraterrestrial or otherwise), and suggestions it could be silencing its own military.

The result is a fascinating read. If you're a UFO enthusiast, you'll find much to enjoy. If you're a cynic, then fear not: you're in good hands. But what you discover may just surprise you. ★★★★★

***Iain Todd** is* BBC Sky at Night Magazine*'s Staff Writer*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Bresser 1.25 inch BinoViewer Deluxe

Price £341 • **Supplier** Bresser UK
www.bresseruk.com

Two eyes are better than one and this binoviewer lets you use both by splitting your scope's single image into two, meaning there's no more need to squint through a single eyepiece. The deluxe version's optical system makes it easier to find focus and get the best views.

2 Orion right-angle viewer for polar scopes

Price £102.99 • **Supplier** Orion
https://uk.telescope.com

Spare your neck when peering through your polar scope with this 90˚-viewer that lets you look at a more comfortable angle. A built-in Amici prism means you can switch to double the magnification.

3 Deep-sky DAD field rotator

Price £415 • **Supplier** First Light Optics
www.firstlightoptics.com

ADVANCED Framing can make or break an image, and this field rotator takes a lot of the aggravation out of getting everything just right. The device has been designed to ensure as little tilt as possible, and can hold a payload of up to 8kg.

4 Orion constellation tote bag

Price £11 • **Supplier** Thread Squirrel
www.notonthehighstreet.com

Carry home the shopping while showing off your love of the night sky with this tote bag, embroidered with the constellation of Orion, the Hunter. Made from 100 per cent cotton, it comes in black, blue and natural.

5 Space 3D 500-piece jigsaw

Price £16.99 • **Supplier** Cloudberries
www.cloudberries.co.uk

Spend an evening or two assembling this 500-piece puzzle to create an image of an astronaut floating above a ringed planet. When you've finished, use the supplied 3D-glasses to watch the cosmos jump to life.

6 Star Walk 2

Price Free (with in-app purchases) • **Supplier** Vito Technology • **https://starwalk.space/en**

Learn to navigate the stars with the help of this app. Hold the device up to the sky and the screen will show you what stars it's pointing at. Consult the 'Sky Live' menu to find out what time the planets, Moon and Sun rise and set that night. For iOS and Android.

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Ezzy Pearson interviews Nora Al Matrooshi

Q&A WITH AN ASTRONAUT CANDIDATE

In April 2021, the UAE announced its second class of astronauts, including its first ever female astronaut **Nora Al Matrooshi**

When did you first want to become an astronaut?
Around the age of five or six. We were studying the Solar System at school and the teacher pitched a tent in the middle of our classroom. When we went in the lights were turned off and she had everything covered in pieces of grey cloth to look like the Moon. That was the day when I decided that I wanted to become an astronaut and see for myself what the surface of the Moon looked like.

▲ **Nora Al Matrooshi: "I really, really want to make it to the Moon. It's what got me interested in space."**

How did you start preparing to become an astronaut?
At times, it seemed impossible, but I chose to study mechanical engineering because I wanted to become an astronaut. I selected the university I went to because I knew that it had an internship programme with NASA. I believe that regardless of whether you want to be an astronaut, you have to develop yourself and gain different skills. If you just focus on one aspect, you're going to be lacking in others. So to be an astronaut, you have to have good leadership skills and good teamwork skills. I tried to be as diverse as possible.

What was the selection process like?
We had to do IQ and psychometric tests, as well as tests measuring technical skills and some teamwork exercises. We also did physical tests, which measured our endurance and strength. Finally I was interviewed by a panel of astronauts. Hazza Al Mansouri and Sultan Al Neyadi, the first two Emirati astronauts, were there and that was a big deal. And then there were two female astronauts from NASA. I got so excited that I was going to ask if I could take a picture with them, but I forgot to ask. I guess now I'll have more chances to ask for pictures!

What did it feel like when you were told you were an astronaut?
It was amazing. Unreal. Obviously, I was ecstatic at that time, but then it actually started to sink in about the role I'd be playing and the amount of responsibility that came with this title of being an astronaut. I'm going to be representing a whole country.

When will your training start?
[Fellow candidate] Mohammed Al Mulla and I haven't started the actual training. That will be next year at the Johnson Space Center in Houston, with the new batch of NASA astronaut candidates. Currently, we're undergoing some initial training at the Mohammed bin Rashid Space Centre in Dubai. We've started learning Russian and we've got our diving licences, and we are doing some survival and flight training.

You're the first female UAE (United Arab Emirates) astronaut. Has your gender affected your path to becoming an astronaut?
No, I believe that everyone was given the same opportunity. For you to select people to represent what you're working on, you wouldn't just pick anyone based on their gender or their last name, because you have to make sure that person is good enough for that role and capable of achieving what you expect of them. One third of the applicants for the second batch of astronauts were female. On the Emirates Mars mission, 80 per cent of the team scientists were women. The chair of the UAE Space Agency and the Emirati Minister of State for Advanced Sciences is actually a woman, Sarah bint Yousef Al Amiri. There are a lot of women in the UAE in space industry.

MORE **ONLINE**

Watch the full interview with Nora Al Matrooshi in the Bonus Content. See page 5 for instructions

What are the UAE's space goals?
The astronaut office at the Mohammed Bin Rashid Space Centre is aiming to build a sustainable and diverse team of competent Emirati astronauts that are qualified and equipped to take on any mission in the future. Currently there are no set missions, but if you have a team ready, you can instantly send them off to any type of mission that would come.

Nora Al Matrooshi was selected as an Emirati astronaut in April 2021 and will join NASA Astronaut Group 23 for training.

What mission do you really want to do?
I really, really want to make it to the Moon. It's what got me interested in space. It's the first memory I have of me wanting to be an astronaut and walk on the surface of the Moon. I'd really like to be part of the Artemis mission.

MOHAMMED BIN RASHID SPACE CENTRE X 2

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Take in a parade of evening planets, enjoy Local Group galaxies and search for binary star Mira

When to use this chart

1 Nov at 00:00 AEDT (13:00 UT)
15 Nov at 23:00 AEDT (12:00 UT)
30 Nov at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

NOVEMBER HIGHLIGHTS

Brilliant Venus is prominent in the western evening sky, still high up when twilight ends, having just gone through a greatest elongation west in late October. It spends the month in the Sagittarius, passing across the Teapot asterism from the 12th to the 20th.

As November opens, a small telescope reveals Venus shaped like a quarter Moon, 26 arcseconds across. It grows as it heads towards inferior conjunction, ending the month 38 arcseconds across.

STARS AND CONSTELLATIONS

November evening skies from mid-latitude Southern Hemisphere locations offer a barren but unique view of the heavens. All around you the Milky Way is hugging the horizon. Above is an unobscured view of the half of the Universe that lies below (south of) the galactic plane. Besides the local stars and globular clusters this is the domain of the galaxies, with three obvious members of the Local Group, the two Magellanic Clouds (high in the south) and M31 (low in the north).

THE PLANETS

Start with Venus, above it is Saturn and then Jupiter, all conspicuous in the western sky. Saturn is not as bright as Jupiter, but they are both prominent in Capricornus. The outermost planets are also on view; Neptune is transiting (due north) during twilight, followed by Uranus, which transits about midnight. A borderline naked-eye object, Uranus's attainment of mag. +5.6 makes it a better target.

DEEP-SKY OBJECTS

Mira (Omicron (o) Ceti), RA 2h 19.3m, dec. -2° 59', is a brilliant variable star and the brightest long period pulsating-type variable. It varies from around 3rd magnitude down to 8th magnitude, with the full cycle taking 330 days. Mira's peak in 2021 is expected in September and by November it is likely to have faded to about mag. +4.5. To help you watch its drop in brightness, a plot of magnitude measurements and a finder chart with comparison stars can be downloaded from the AAVSO website. Mira's next minimum is expected in March 2022 (close to conjunction).

Located just 1.7° west of Mira is a pretty 6th magnitude double star, 66 Ceti (RA 2h 12.8m, dec. -2° 24'). The component stars are mag. +5.7 and +7.7, appearing yellow and white respectively, separated by a comfortable 17 arcseconds.

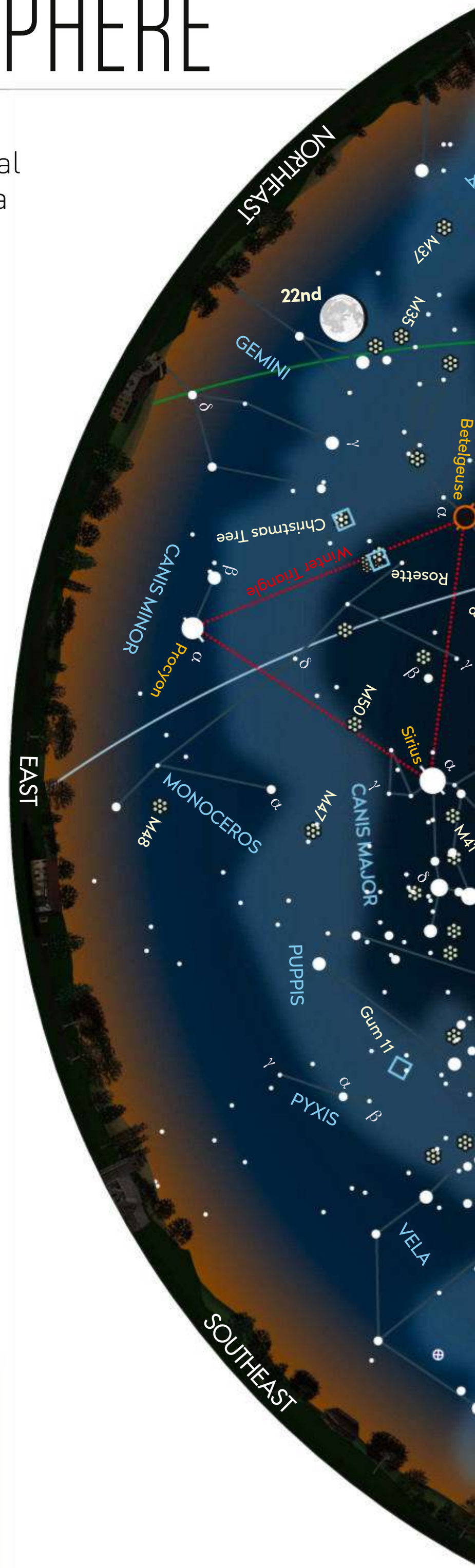

CHART: PETE LAWRENCE

Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET
- STAR BRIGHTNESS:
  - MAG. 0 & BRIGHTER
  - MAG. +1
  - MAG. +2
  - MAG. +3
  - MAG. +4 & FAINTER

NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
Capella
PERSEUS
Almach
M34
Algol
NGC 1499
AURIGA
M36
ANDROMEDA
M110
M31
M32
NGC 752
TRIANGULUM
M33
Hamal
ARIES
Pleiades
TAURUS
Elnath
PEGASUS
Alpheratz
Great Square of Pegasus
Markab
Aldebaran
Hyades
19th
Ecliptic
Uranus
Menkar
16th
PISCES
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Celestial Equator
Mirror of Venus
Mira
Circlet
Steering Wheel
Enif
M15
EQUULEUS
M42
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ERIDANUS
CETUS
Neptune
13th
M2
AQUARIUS
LEPUS
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CAELUM
HOROLOGIUM
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PISCIS AUSTRINUS
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Saturn
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RETICULUM
PHOENIX
Achernar
Canopus
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LMC
Tarantula Nebula
NGC 362
47 Tucanae
SMC
TUCANA
INDUS
GRUS
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VOLANS
MENSA
HYDRUS
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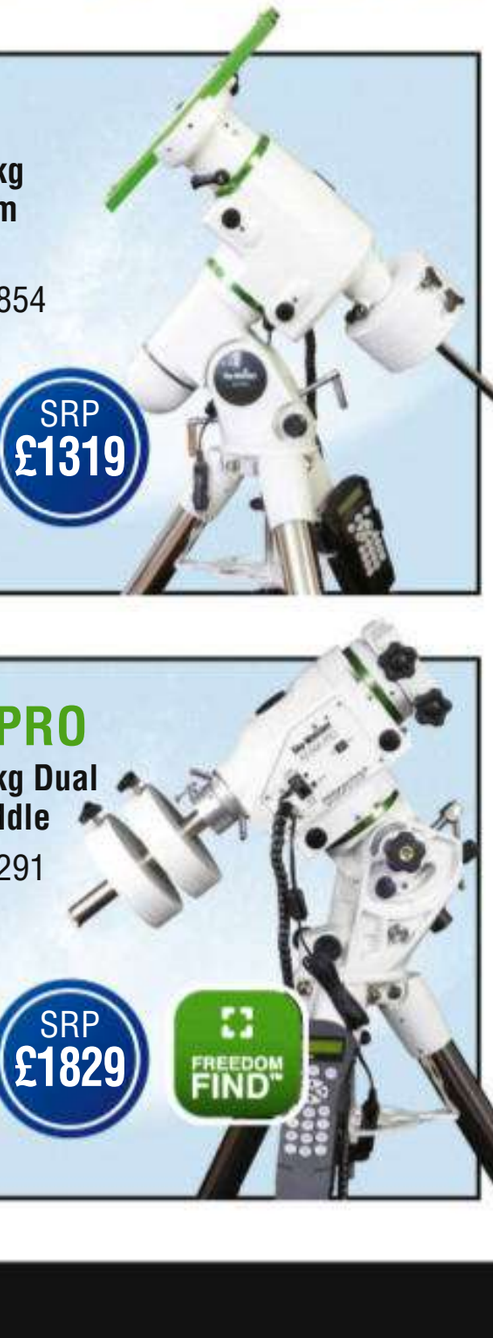

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